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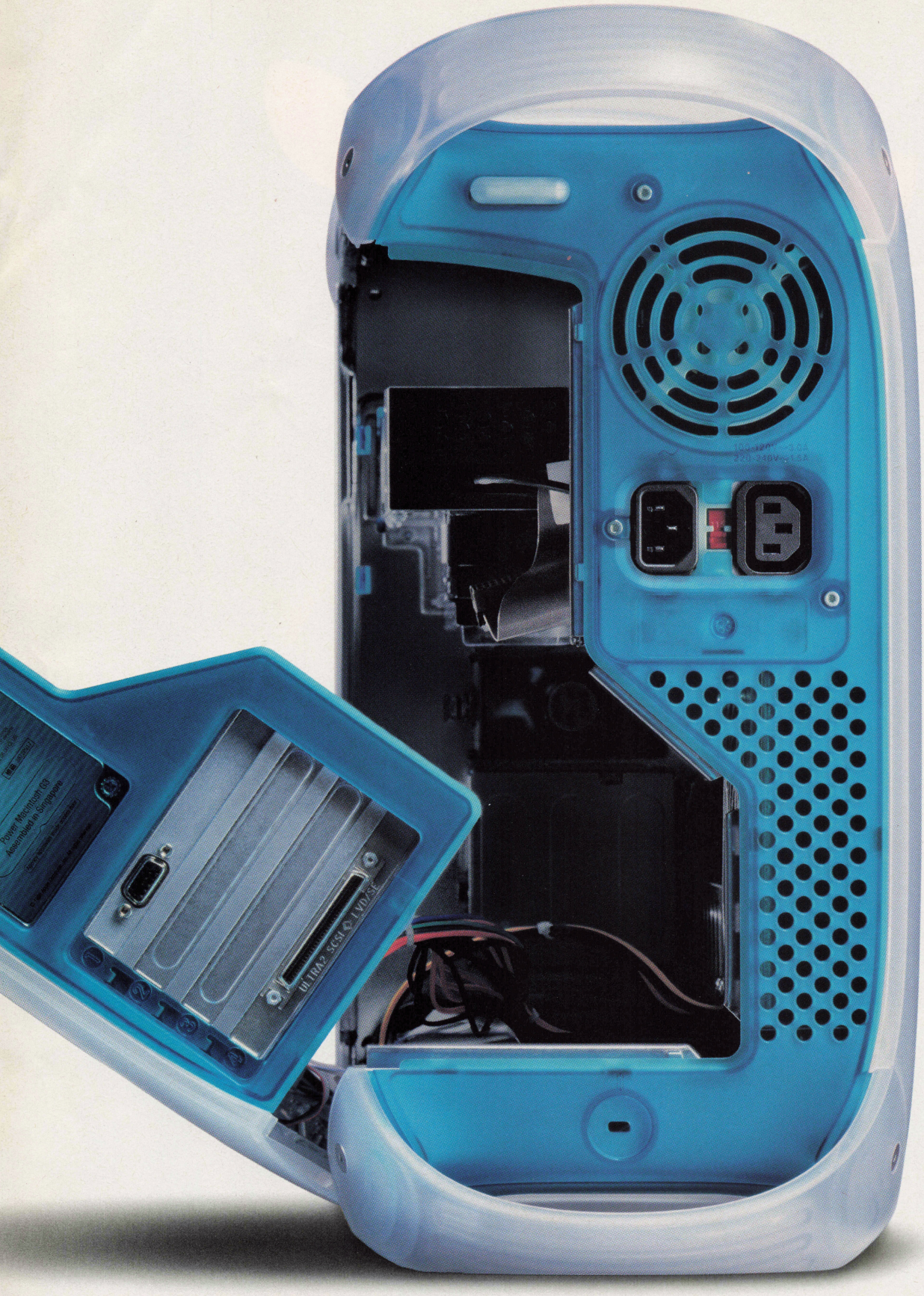
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Tom Kluyskens, Alias|Wavefront

ON THE COVER

Tom Kluyskens of Alias|Wavefront created this unretouched image, titled "Better Times," in Maya, using procedural textures for color, transparency, specularity and bumps. No painted textures were used. To read more about procedural animation, see page 32.

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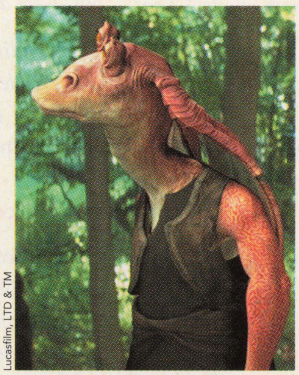
The Stars of Star Wars

When *Star Wars Episode I: The Phantom Menace* first opened, the staff of *Computer Graphics World* played hooky with millions of other adults and kids across the country and went to see the film at a theater with the biggest screen and the best sound system we could find. We had to do it, I figured. After all, this was the biggest computer graphics movie event of the year. And, for professional reasons, we had to see if the digital effects and characters lived up to their advanced billing.



Lucasfilm, LTD & TM

A few minutes into the film, however, I was surprised to find myself concentrating as much on the story as on the graphics. Indeed, I was intrigued with the way the movie explored variations on classic science-fiction themes—how it transported us to a time and place where good conquers evil, where heroes and heroines use special skill and ingenuity to defeat villains; where ancient knowledge is passed on to a new generation; where all beings, even the most misfit, find acceptance; and where we all can escape to places we've never been and imagine things we've never dreamed before.

The fact that the virtual scenes and actors had enhanced, rather than detracted from, these elements of storytelling convinced me that they had indeed played a starring role. When we returned to the office, I wondered if the rest of the staff came away with the same impression. So I sent around a brief survey and asked for their thoughts on the contribution computer graphics made to the film. Here are the questions and a sample of some of the most insightful and interesting answers:

- **What was so intriguing about the film that it compelled so many people to skip work and school to see it (and set an opening day box office revenue record of more than $28 million)?**

The original trio of movies set up an appealing, unique, and in a strange way, believable world. If you liked it, and many people liked it quite a bit, it would be only natural that you would want to see more of that world. Also, since the original Star Wars *came out, George Lucas has achieved power and wealth of legendary proportions. People were curious to see the end result of one man's dream combined with all that backing....*

Everyone knew that the visual effects would be bigger and better and more spectacular than anything they had seen before, that the good guys would win (mostly), that there would be some good humor and a lot of action without bloody violence. Episode I *continues a familiar and well-loved story that was only just begun. Who wouldn't want to see it? The big question is why would anyone want to see it twice? And I think the answer is that you have to see this movie at least twice to fully appreciate it. The first time, you can't possibly see everything that's going on. The second time you know where the story is going, so you can take your eyes off the action and start exploring the whole scene....*

For someone weaned on science-fiction literature, Star Wars *made the perfect transition to film of the major themes played out in all captivating science-fiction literature. Still a kid at heart, I was excited to lose myself in another magical episode....*

continued on page 6

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continued from page 5

The movie was appealing because of Darth Maul, Sith Lord....

• Did the graphics live up to expectations?

Critics may look for ground-breaking plots and deep meanings, but audiences just want a good story. The state-of-the-art computer graphics made it easier than ever for viewers to thrust themselves beyond the screen and into the scenes. Even the most far-fetched characters projected an aura of reality beyond anything witnessed yet in film....

I spent most of the movie going, "Wow, look at those effects!" That might be partly because of what I do for a living, but I doubt I was alone in that. I certainly wouldn't say the graphics overshadowed the human characters. They made up for their lack of character....

The only thing that didn't seem real to me were some of the painted backgrounds. Otherwise, the realism was truly awesome; the amount of detail, incredible....

There was not enough of the Sith Lord, and he dies, ugh....

• Which were your favorite and least favorite digital characters?

I liked the pod-race announcer(s) because of the creativity of their being (dueling sportscasters' heads on one body) and the nod to commercialized sports. My least favorite character was probably Jar Jar, because he seemed to be a stereotype animated. And I couldn't understand half of what he said....

Jar Jar's character was particularly annoying. But that was because of the voice and the tired sight gags. He was actually my favorite character in terms of CG, and my least favorite in terms of everything else. Also, Boss Nass, the Gungan leader, was not a favorite of mine. The digital spittle was gratuitous, as though it had been calculated to please small boys, which it probably didn't even....

My favorite was Jar Jar Binks. Considering he had a major part and appeared throughout the movie, he had a lot of opportunities to fail as a believable character. But almost every nuance of his persona was excellently executed....

I liked all of them, but Jar Jar is the greatest because he made me laugh....

Even though Darth Maul looked to have only face paint, he was still the best character....

• What were your favorite and least favorite digital scenes/sequences?

The Gungan/droid battleground was unsurpassed in its realism. The amount of action and detail and the fast pace made me forget it was all digital. But for visual effect, the beauty of the Gungan sea kingdom was incredible....

The best shot was the battle scene, when the bubble shield was created over the Gungan army. It was cool, surprising, and it just worked very well....

The scene I liked was when Qui-Gon, Obi-Wan, and Jar Jar went to the underwater world and passed through the membrane surrounding one of the Gungan cities. The scene I liked least was when Qui-Gon and Obi-Wan first landed on Naboo; it kept switching back and forth from looking real to fake....

The underwater chase sequence was my favorite. The sea creatures were of the same high quality as the Jurassic Park *dinosaurs. The way the first enormous fish blended in with the scenery with its coral-like appearance was the best aspect of the scene....*

The entire pod-race sequence, from the pre-race through the settling of the bets, was my favorite. The destroyer droids (the ones that roll out) were also terrific....

The blending of aliens into the set of the Jedi Knights' meeting room was excellent. But the view out the window, with the continuous stream of airborne vehicles whizzing by, was disappointing. The vehicles stood out as the most artificial CG in the film....

• What could be improved?

Lucasfilm LTD & TM

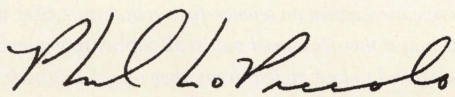
Clearly, George Lucas is in control of the graphics and imagery. Now if only a meaningful story could be wrapped around that, bliss would be achieved. Also, the actors looked as if they were instructed to play a secondary role to the visual effects. Maybe I'm old-fashioned, but I wanted more from the human elements, more compassion and feeling. The most human qualities belonged to Jar Jar and Watto, the junk dealer....

The first movies in the series were (save some primitive visual effects) flawless. They had the right mixture of adventure, mystery, comedy, even romance. But even though the graphics were more sophisticated in this episode, it lacked the character depth and plot development of the previous three films....

The graphics were great, but wasted on frivolous characters. The movie seemed more like a timid Disney Ride. Where were the sinister villains? All the bad guys seemed like misguided buffoons, not threatening at all, except for the Sith Lord. But even his character was underdeveloped....

I was impressed with the CG characters and effects, but The Phantom Menace *points to the fact that these elements can no longer "make" a good movie. They might have been enough when* Jurassic Park *came out, but now people expect more, namely, character development and a good story line. CG should be considered and used as one set of tools among many available to moviemakers for telling a story. At this stage of the game, producers should first consider the story they want to tell, then decide which tools (digital, mechanical, human, or otherwise) will enable them to do that best....*

That's a brief synopsis of what our in-house movie reviewers had to say about the role of graphics in *Star Wars Episode I: The Phantom Menace.* Do you agree, disagree, have other views? Please drop us a line and let us know.



Phil LoPiccolo: Editor-in-Chief

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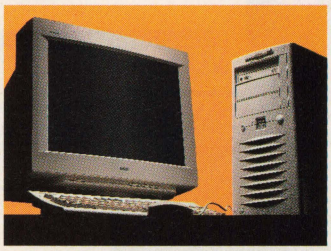

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More Previs Prehistory

Some clarifications are in order with regard to the reply from Debra Kaufman that appeared in the Letters section of the June 1999 issue ("Previsualization's Prehistory," pg. 8). The first ILM/CG department previs was used in 1986 for the "Star Tours" ride, using an E&S PS2.

Prior to that, the Lucasfilm Computer Division did employ similar techniques, using custom software on the Pixar Image computer and hardware from Sun Microsystems. This work was not, however, used to previs for live-action footage, but rather for the first all-CG film sequence, the Genesis Effect in the movie *Star Trek II: The Wrath of Khan.* And this was still only 1982.

The very first CG previsualization was used at Robert Abel & Associates in the mid- to late 1970s. It involved vector graphics generated on an E&S and was used to program the motion-control cameras in live-action television commercial work. This concept was a direct result of Con Pederson's work with John Whitney Sr., dating back to the late 1960s, and which incidentally included technology used in the feature film *2001: A Space Odyssey.*

Many details about who wrote Abel's software and how it was integrated can be found in my new book, *CG 101: A Computer Graphics Industry Reference,* which will be available at Siggraph this month. The book's unique and comprehensive history of computer graphics was collected from hundreds of personal interviews with people whose experiences in computer graphics date back to the 1940s. I wrote it to dispel the myth that CG is a 1980s and 1990s phenomenon.

CG's "infancy," as Ms. Kaufman states, was truly in the 1960s, with the earliest computer-assisted graphics techniques being used as far back as the late 1940s.

The book includes a separate previsualization article by Colin Green of the Pixel Liberation Front. Colin and I both worked on the Luxor project in 1992 to 1993 with the image engineering previsualization department of Douglas Trumbull's company. (I was the department's supervisor). More information about the book can be found online at http://visualfx.com/cgi-book/cgibookinfo.htm.

Terrence "Tman" Masson
San Rafael, CA.
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Editor's Note:

Those interested in who did what when from the earliest days of computer graphics should also check out the time line on page 64 of this issue. The time line is based on the full-length documentary The Story of Computer Graphics, *which will premiere at Siggraph this August.*

Our New Web Design

For several month's now, Computer Graphics World's *Web site has had a new look. Many readers have responded to the changes, and we offer below representative samples of their letters to us: —Jenny Donelan, Managing Editor*

School Listings

Whatever happened to your suggested list of schools and institutions for computer graphics and animation? More important, do you have a current list ranking graduate programs in computer animation at various colleges and universities?

Pradeep Mistry
Mitchellville, Maryland

We decided to bypass the list, at least for the time being, in favor of focusing attention on our other online content, not the least of which is the Gallery. However, I know of several guides to animation schools. One, Gardner's Guide to Computer Graphics, Animation, & Multimedia Schools, *by Garth Gardner, is available from www.ggcinc.com. Two others,* The Complete Guide to Animation and Computer Graphics Schools *by Ernest Pintoff and* The Art Student's College Guide, *by Linda Sweetow et al, would be easily found on the Web. I'm sure one of these books would at least provide a foundation on which to base your research.*

Model Shop

Congratulations on a beautiful new site design. But there is just one problem: I can't seem to find the old Model Shop tutorials and archives anymore. I'm looking in particular for the Maya tutorial in which your author created "Senator Bob." Do you know where it is?

Cheng-Lun Chung
Internet

All the archives for Computer Graphics World, *including the tutorials, back issues, and gallery, are awaiting inclusion in a new database that is being rolled out by our parent publishing company during the next several months. Once that happens, all our content will be fully searchable—as well as available once more.*

We Value Your Input

We welcome any insights you may have that would further our readers' understanding of topics discussed in this issue. We may edit your response to conform to our style and space requirements.
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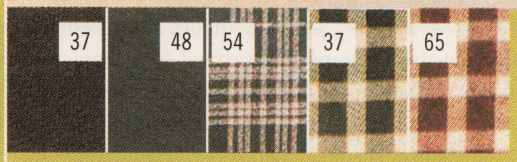

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Modeling With Feeling

A few years ago, the graphics community was wowed by the introduction of a unique interface called the Phantom that let users "feel," via force-feedback technology, the 3D digital objects they were looking at on screen. The product set the minds of artists, designers, and scientists reeling as they conceived lists of potential applications for the technology. The subsequent development of a software developer's kit (SDK) called Ghost, brought some of the potential applications closer to fruition. However, it's the latest product from SensAble Technologies—the company that brought the Phantom and Ghost SDK to market—that is expected to have the greatest impact on the graphics industry. Called FreeForm, the system provides the hands-on, "digital-clay" technology that animators and industrial designers in particular have been clamoring for.

FreeForm integrates a new digital-modeling metaphor with the Phantom's patented 3D Touch capability to let users create and explore form intuitively in 3D. The product is intended to supplant the last non-digital holdout in both content-creation and product-development applications: physical conceptual models. In both the engineering and entertainment domains, designers and surface modelers still rely heavily on physical models during the conceptualization process. Using amorphous clay or blue foam, sculptors create forms and shapes that are difficult to represent via math-based models. The physical models are then digitized and brought into CAD or surface-modeling software for further development. By replacing this physical-modeling component with a digital process, FreeForm eliminates the need for scanning, and the potential inaccuracies associated with the physical-to-digital conversion. Intended to complement rather than replace downstream modeling tools, FreeForm files can be exported to commercial-surfacing or CAD software for refinement.

The FreeForm interface is a stylus that serves as a handle for a sculpting tool that can be custom-developed or selected from an existing library of tools. Modelers can either use the tools to carve and smooth digital clay or to wire-cut 2D shape profiles from digital blue foam. The interface and modeling processes are intended to be highly intuitive to sculptors and modelers. "[With FreeForm], our traditionally trained sculptors are able to easily parlay their skills into the digital realm," says Derald Hunt of Klieser Walzcak Construction Co., an animation production studio and FreeForm beta site that historically has relied heavily on physical sculptures to achieve organic human forms. "Our sculptors are trained to create plasticene sculptures, from which we then cast models for digitizing," says Hunt. "We've taken those same people and put them in front of FreeForm, and they're very comfortable. They can knead the model, mold it, and add to it—just as they would with their traditional tools. Then the models can go straight into another animation package. We can skip the time-consuming digital conversion." It is, he believes, a product that has the potential to "revolutionize" digital-production processes.

In addition to virtually carving clay and cutting foam, FreeForm provides features that are exclusive to digital media. Among these are six levels of undo, which give users the freedom to experiment with shapes without having to re-create the entire model at each wrong turn; a mirroring tool, which can cut the production time of laterally symmetrical models in half; and copy/paste functionality to speed the modeling of redundant components (spikes on a golf shoe, or ridges on a tire). FreeForm also lets users control such factors as clay hardness and friction. The product is particularly suited to the creation of highly stylized or organic objects, which are notoriously difficult to represent in CAD. Users can import a CAD model into FreeForm, then carve the detailed or tiny features absent from the base model. Users are also able to sculpt a model from behind, or from the inside out. In designing the eyebrow of a character, for instance, modelers typically add clay to the area, then carve it back to the eyebrow shape. With FreeForm, users can go inside the model and push out the eyebrow shape.

Because FreeForm is software-independent, any CAD or surface model that can be exported as an STL file can be imported into the system for manipulation. To export FreeForm models into CAD or surface-modeling software, users either can get a set of 2D slices from the 3D model and export the slices as IGES curves, which can then be rebuilt as a parametric surface in the CAD software, or they can output an STL file for import into an animation program. Additionally, the FreeForm polygonal meshes can be imported into one of the new third-party tools on the market that translates polygonal data into NURBS surfaces.

FreeForm, priced at $15,000 for the haptic interface and modeling software, runs on Windows NT 4.0 and requires a dual-processor 300MHz Pentium II system with 512MB of RAM and at least 70MB of available hard-disk space. (Cambridge, MA; 617-621-0150; www.sensable.com)

—Diana Phillips Mahoney

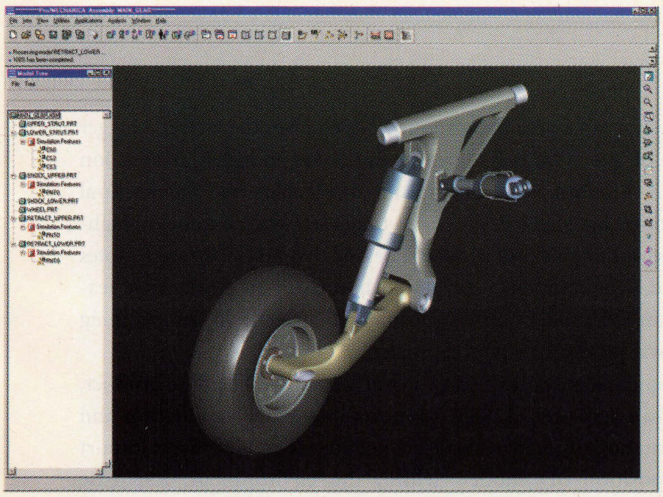
infoNOW 121

PTC Brings Analysis to Designers

Pro/Mechanica 2000i from Parametric Technology Corp. (PTC) equips design engineers with simulation and optimization capabilities that can be used to eliminate design problems early in the process. Much of the program's functionality is automated and can be accessed through an easy-to-navigate user interface that includes menus, on-line help, and tutorials.

"Pro/Mechanica 2000i is aimed at both analysts and advanced mechanical engineers who need a robust complement of MCAE tools to perform a fairly full range of analysis on products, but who would benefit from an easier to use, more automated set of controls," says analyst Bruce Jenkins of Daratech (Cambridge, MA). The new application integrates with other members of PTC's i-Series, such as Pro/Engineer and CADDS 5, and also with third-party packages such as Catia from Dassault Systemes and Unigraphics from Unigraphics Solutions.

Pro/Mechanica consists of different modules: the foundation program plus motion, structure, and thermal packages. The motion-simulation module lets engineers create, evaluate, and optimize the motion of an assembly in a real-world environment. The structural package enables



the evaluation and optimization of static and dynamic structural performance, while the thermal-simulation module allows engineers to assess the performance of parts and assemblies subject to thermal loading. Each module costs $10,000. (Waltham, MA; 781-398-5000; www.ptc.com)

—Jenny Donelan

infoNOW 122

Vendors Take the Be Train

The BeOS, the operating system for digital-media applications introduced by Be Inc. (Menlo Park, CA) in 1997, has gained ground in recent months. Several vendors have announced support for the platform, including 3D applications developers MetaCreations (Santa Barbara, CA), Nichimen Graphics (Los Angeles), and Strata/C-3D (St. George, UT).

MetaCreations will be porting Bryce 4, its popular terrain-generation and animation program, to the BeOS for release in the second half of 1999. Nichimen Graphics has announced that it will be making its Nendo 3D modeling tool available for the platform, with a beta version to preview at Siggraph. And Strata is developing Be versions of its 3D modeling and animation package, StudioPro, and nonlinear editor, VideoShop.

Other graphics applications being developed for the BeOS include Moho, a 2D vector-based animation package from Lost Marble (New York), and Easel, a 2D painting and photo-retouching program from Human Touch (New York).

The BeOS, which runs on Intel-based machines, features a multithreaded design that allows the system to respond to user input even when busy with other tasks. The latest version, BeOS 4.5, also features a 64-bit file system that can manage disks and files millions of gigabytes in size.

You Can Be an Avatar

AvatarMe (London) will be generating photorealistic 3D avatars of visitors to its booth at this year's Siggraph (#447). Individuals wishing to have avatars made of themselves will enter the company's AvatarBooth, where multiple images will be scanned, then combined to form lookalike avatars that can walk, run, and jump. The process will take just several seconds, according to the company.

In Brief

3D modeling developer **Spatial Inc.** (Boulder, CO) has announced that it intends to acquire **Sven Technologies** (Palo Alto, CA), a provider of 3D software visualization products for industrial and architectural design.... The **MacNeal-Schwendler Corp.** (Los Angeles) has announced that it will change its name to **MSC Software Corp.** MSC has also agreed to acquire **MARC Analysis Research Corp.** (Palo Alto, CA), a developer of simulation software for nonlinear analysis, for approximately $36 million. .... Fabless semiconductor manufacturer **Pixelworks** (Tualatin, OR) has received $11.6 million in venture capital from several investors to fund efforts to create processors for the flat-panel display market.... **Tecnomatix** (Herzliya, Israel) and **Tecmath** (Kaiserslautern, Germany) have agreed to integrate Tecmath's human models into Tecnomatix's CAPE product line, for the simulation of human operations.... Digital studio **Cinesite Europe** (London) has acquired special-effects house **Effects Associates** (London).

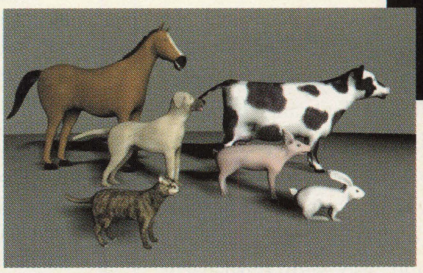
—Jenny Donelan

New Forms of Life

Version 3.5 of Credo Interactive's venerable 3D character animation software, Life Forms, features significant advances in motion editing, rendering, user-interface design, import/export, and the retargeting of motion between different characters.

At special-effects house Brainchild Studios in White Rock, British Columbia, animators have been using an early version of 3.5 for a kind of preflighting. "After we've set up our [LightWave] characters, and they're ready to animate, we use Life Forms to see how everything is bending and so forth," says creative director Ed Konyha. Life Form's ready-to-use animations provide a quick way to view problems in the models before going on to the more time-consuming process of animating them in LightWave. "Prior to 3.5, there were export problems," says Konyha. "But now, the program has been quite useful."

Credo has also recently introduced Animania, a line of ready-to-use creatures that can be downloaded from the Web. The menagerie currently includes a horse, cow, pig, rabbit, dog, and cat, though additional animals will be added over the next several months. Each model comes with basic motions such as walking and running in addition to movements peculiar to the animal-grazing, hopping, etc. The Animania models are available for a variety of programs, including Life Forms, LightWave 3D, 3D Studio Max with BonesPro 2, and Maya, with expanded compatibility to be added later this year. Each animal comes as a segmented model or a mesh model with bones.



Life Forms 3.5 is scheduled to ship this month, at a price of $299. This version is compatible with a number of file formats including StudioPro, trueSpace 4, Poser 3, ElectricImage, and Cinema 4DXL. Life Forms Studio 3.5, Credo's professional-user version, comes with Credo's PowerMoves 1&2, a set of 3D animation and motion-capture libraries, and is compatible with file formats including PowerAnimator, Maya, LightWave 3D, Inspire 3D, 3D Studio Max, and others, as well as motion-capture data. The cost is $495.

The Animania creatures, available now on Credo's Web site, range in price from $99 to $299 per download, depending on file format and compatibility. (Vancouver, BC; 604-291-6717; www.credo-interactive.com)

—JD

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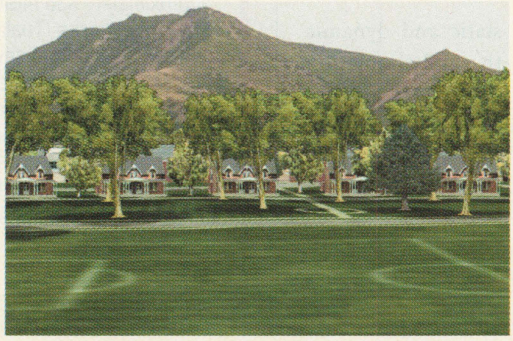
Visualizing Land Development

Evans & Sutherland, a longstanding leader in the development of high-end simulation systems for the defense industry and large-scale commercial manufacturers, is targeting a smaller, more focused audience with its latest visualization product. Called Rapidsite, the software is a 3D visualization system for urban and suburban planning and development. With it, users can create photorealistic models of large areas (up to 50 acres), including new and existing buildings and landscapes, which can then be explored interactively in 3D. The simulated environments enable what the company calls "in-context visual impact analysis," whereby all parties to a development project can explore and better understand the visual impact of a proposed development. Rapidsite runs on Windows NT computers with OpenGL acceleration. Imported CAD, GIS, and digital-image files provide the building blocks for model creation. The software is AutoCAD-compatible, so it can utilize DWG files of proposed buildings and new and existing site plans and contours.



To enhance photorealism, Rapidsite relies on digital photographs to represent existing buildings and to create panorama models. "[Rapidsite] cleverly uses photo images for large-area backgrounds, which gives the viewer a bigger sense of the proposed development," says industry analyst Jon Peddie (Tiburon, CA). Though urban planners and architectural developers have historically been a tough sell when it comes to high-tech wizardry, this product could be one that breaks through, notes Peddie. "The company really did its homework to get the right features in the product and to position it correctly in the planning approval process of a typical project."

Rapidsite is available in two configurations. The base product, Rapidsite Explorer ($1995) supports interactive exploration and presentation of photorealistic environments and lets users import and position 3D models within the environment. Rapidsite Creator ($5990) adds model creation for terrain, vegetation, new and existing structures, and panoramic backgrounds. The software can be coupled with Evans & Sutherland's high-performance 3D hardware accelerators for peak performance. (Salt Lake City, UT; 801-588-1000; www.es.com)

—DPM

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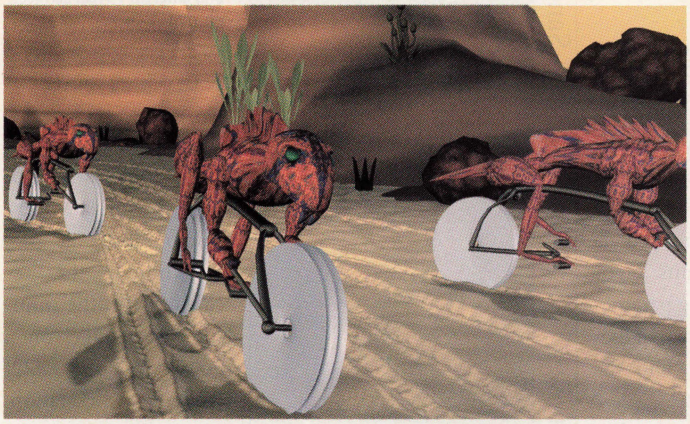
Breaking New Ground



Alien bikers speed through the countryside, deforming the terrain beneath their tires as they go. Using a ground-simulation system, Georgia Tech researchers can automatically re-create the impact of rigid models on the appearance of the ground.

Animators have made tremendous strides in the development of characters that not only look realistic but also move through space in a physically believable manner. Because of the computational intensity of such a feat, however, the environment in which these characters move has typically received only cursory attention. In fact, "real enough" is often the mantra animators repeat when it comes to re-creating subtle environmental details. Fortunately, as workstations with increased processing power have become more readily available, and as techniques for realistic character animation continue to become more powerful, animators are broadening their focus from beyond their characters to their characters' worlds.

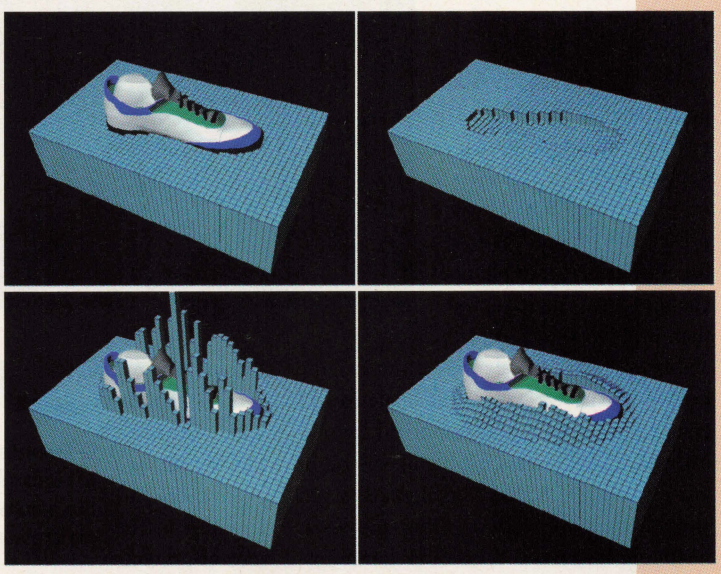
An example of this expanded view can be seen in a recent project by researchers in Georgia Tech's Graphics, Visualization, and Usability (GVU) Center. The team developed a model for simulating the impact of character movement on various terrains, such as sand, mud, and snow. Specifically, the software gives animators the ability to automatically simulate the impact of rigid models on the appearance of the ground. "In general, we wanted to be able to collide anything with the ground and see the effect," says GVU's Jessica Hodgins, who worked on the simulation code with Robert Sumner, a former Georgia Tech undergraduate who conceived the project, and James O'Brien, a Ph.D. candidate at the university. In addition to obvious results of ground impact, such as footprints and tire tracks, says Hodgins, "there are more subtle effects that you want to be able to handle. For instance, if something skidded in the sand, you'd want a pile of displaced sand to appear in front of the skidding object."

Making Tracks

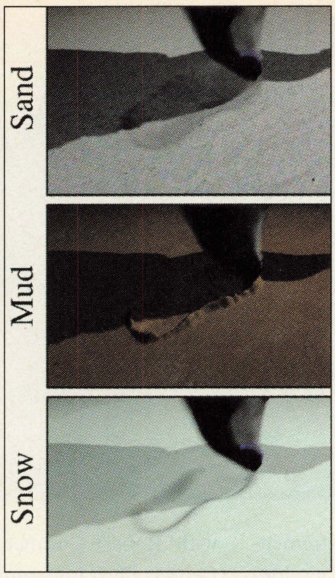
The underlying hypothesis for this project, says Hodgins, was that characters will look more connected to their environment if they leave tracks in the ground. The ability to simulate such effects is particularly well suited to entertainment applications. "There have been animated movies where trails have been added, like in *Mulan*, when the characters come over the hill and leave tracks in the snow. This is an automatic way of being able to do something like that," she says.

The GVU code uses displacement and compression to deform a volumetric ground model based on the impact of rigid geometric objects at each time step. The ground model consists of a height field divided into a uniform rectilinear grid in which each point represents a vertical column of material. The material properties vary depending on the terrain being simulated. The push of rigid objects into the grid (determined using dynamic simulation or keyframe or motion-capture data) changes the height field at the top of the columns.

Among the sample animations developed by the research team to illustrate the simulation capability are a runner making footprints in sand, mud, and snow; a runner falling; a cyclist making tire tracks; and a cyclist crashing. For the runner simulation, says Hodgins, "we first computed the motion of the runner, so we knew where the runner's foot was going to go. Then we made an approximation that said the foot could go some distance—two centimeters, for example—into the ground. The placement of the foot as specified by the simulation of the runner interacts with the ground simulation."



The push of a foot into a rectilinear grid representing a ground model deforms the height field to simulate the effect of the collision on the ground surface.



To realistically represent the impact of an object's collision with different terrain surfaces, the GVU simulation code incorporates specific parameters for the different surfaces.

That interaction determines the height of all of the columns.

The surface-simulation algorithm the researchers developed actually comprises four separate algorithms. The first handles collision-detection and response, determining whether the rigid object has hit the surface and reducing the height of the affected column appropriately. Next, a displacement algorithm compresses the material under the object and/or forces it outward. An "erosion" algorithm modifies or erodes the steepness of affected columns relative to neighbor columns to produce a realistic mound of dirt, snow, or other material. Finally, a particle system is implemented to simulate material thrown into the air as a result of the impact.

The simulation code includes adjustable parameters for controlling the differences between various terrain surfaces. For example, users can change the shape of ground-material mounds by adjusting parameters for the inside and outside slopes. They can control the irregularity of the ground deformations by specifying roughness and can vary the wetness of the material by adjusting its liquidity. A compression parameter allows users to vary the substance density by adjusting the amount of displaced material. In addition, users can control the look of material sprays generated via the particle-systems algorithm by modifying parameters for such factors as adhesion, particle size, and the material fall-off rate.

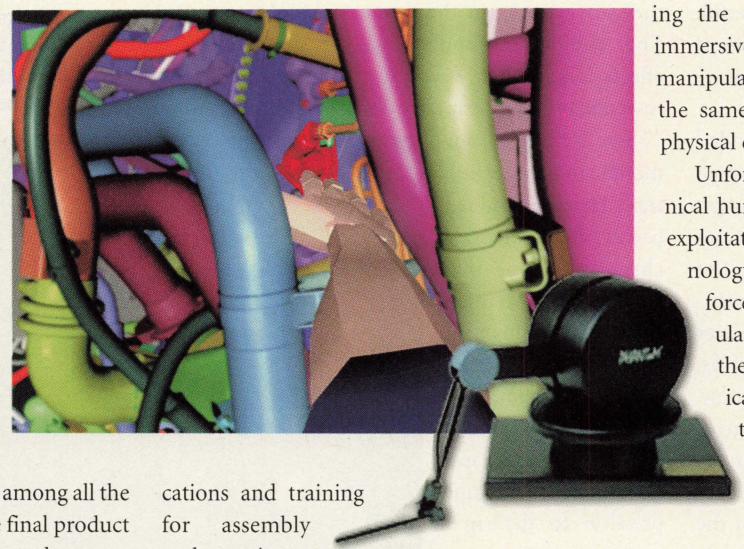
To help users visualize the results of the surface simulation, the ground-surface model is texture-mapped, and the height of the columns at each time step is rendered with Pixar's RenderMan using a single polygon with a displacement shader. To date, the surface-simulation code can only generate smooth surfaces and particles, precluding the representation of certain effects, such as clumps of crusty mud. Additionally, while the simulation is fundamentally based on physics, says Hodgins, "it's not a completely accurate model. For efficiency reasons, you have to decide what level of approximation you're going to do. You're obviously not going to simulate every grain of sand."

Although the researchers run the simulation in parallel on a multiprocessor SGI Challenge workstation, "it can run on almost anything," says Hodgins. "It's just computing the height of the columns, and at that level it's only C-code. Then you'd output it to render it later." While the technology may be slightly beyond the scope of what can be done easily in today's commercial software programs, "it's approaching the point where it could be made a plug-in. Computationally, it might be feasible, but it is still on the edge."

Diana Phillips Mahoney is chief technology editor of Computer Graphics World.

Giving Engineers the Magic Touch

In the manufacturing world, interactive digital mockups are beginning to supplant full-scale physical mockups as a medium for assessing the form, fit, and function of a new product's components before mass production. The primary advantage of such an approach is that it fosters a more cost- and time-efficient production process. It's easier, for instance, to implement changes to a digital model than a physical one. And the ability to share a digital model among all the people who have a stake in the final product enhances communication among the group early on, thereby reducing the likelihood of last-minute overhauls. Digital models can also be used for various other purposes, including internal and external communications and training for assembly and maintenance. Perhaps even more intriguing is the idea of presenting the digital mockup in a fully immersive virtual setting, so users can manipulate the virtual model in much the same manner as they would its physical counterpart in the real world.



GE Researchers use a haptic interface in conjunction with custom software to simulate physical interactions with models for digital mock-up applications and for assembly training and maintenance.

Unfortunately, one stubborn technical hurdle stands in the way of full exploitation of digital-mockup technology: the absence of realistic force-feedback sensations to simulate physical interaction with the digital data. Though not critical for marketing and presentation applications, realistically re-creating the sense of touch can be especially important to certain design, maintenance, and training applications, in which many tasks could be streamlined through full sensory engagement. With a haptic-interac-

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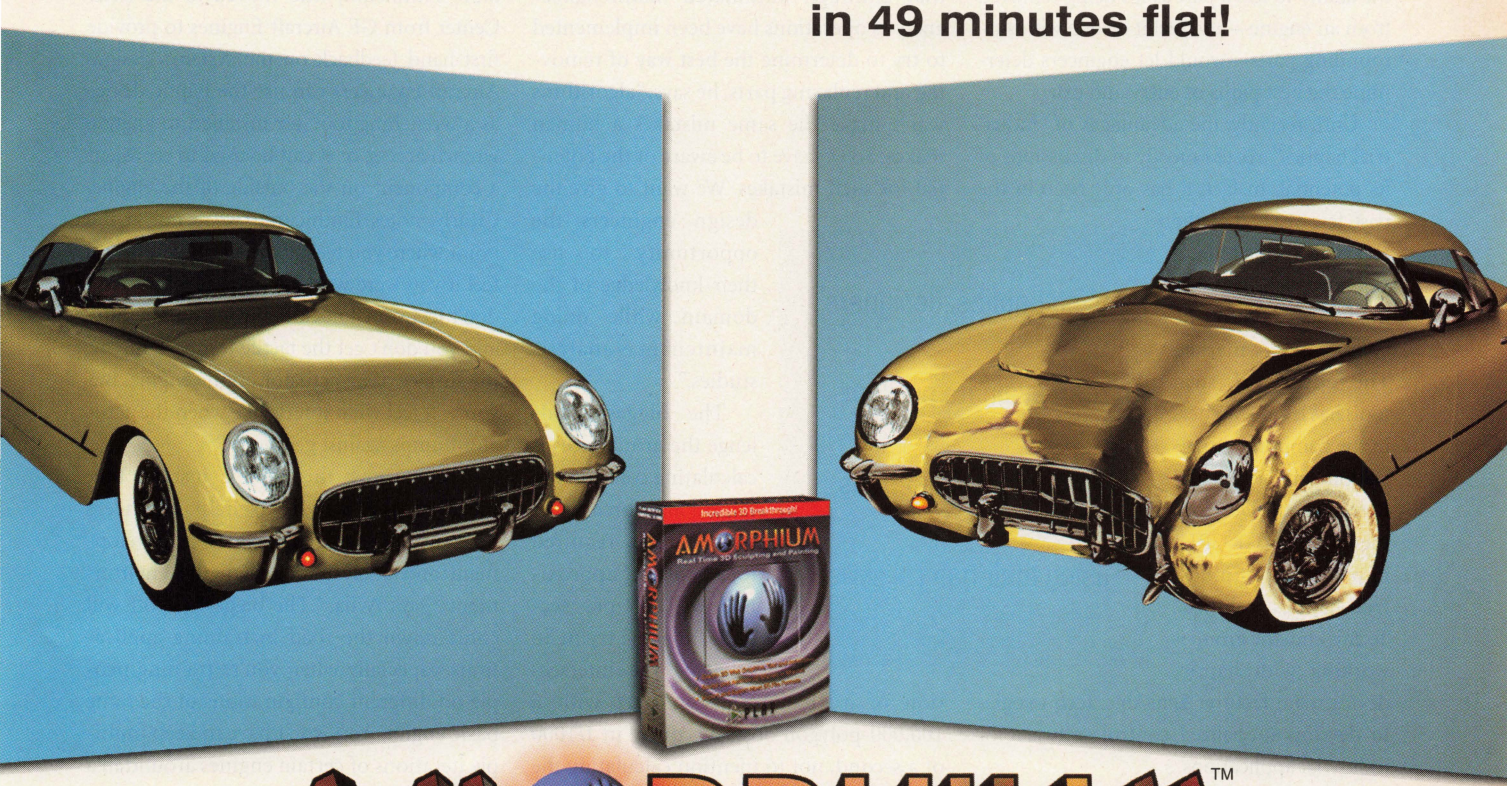

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tion system, for example, designers would be able to evaluate potential product-assembly sequences using their natural mechanical skills rather than a complex user interface. Additionally, in maintenance applications, the ability to feel a part as it's being removed from an engine—and feel it collide with surrounding parts—would let engineers determine the best paths of entry and exit.

Until recently, the advantages of "industrial haptics" existed mostly in discussions of its potential. In fact, it has only been in the past few years that the ability to simulate realistic force-feedback has made its way to the commercial market. The advent of such tools has led researchers in the computer visualization lab at the GE Research and Development Center (GE CRD) in pursuit of an industrial-haptics solution. To this end, the group is working with haptic-device manufacturer SensAble Technologies to develop specialized control software for industrial applications.

With haptics, designers can evaluate product-assembly sequences using their natural skills.

"Specifically, we're trying to simulate the physical interaction of one part with one or many other parts," says Ricardo Avila, a researcher at the Center. "There are certainly ways right now that you can simulate part removal and replacement without haptics. But they involve time-consuming analyses, possibly taking up to a couple of days. In a haptics environment, those types of analyses can be done in under an hour."

The Center's "customer" for this project is the GE Aircraft Engines division developing the F120 engine for the Joint Strike Fighter application. One of the primary objectives of the project, says Avila, "is to bring folks with a maintenance background into the CAD world, but enable them to work in that environment the way they're used to working—with their hands.

"Expensive physical mockups used to be accessible to large numbers of people, including maintenance people, who could take a look at a new design, try things out, and comment on it," says Avila. "One of the tradeoffs we made when we went to this purely digital world was that these people were sort of shut out. They could see the designs on screen, but they couldn't get their hands on them." Another drawback is that although automated maintenance-analysis operations have been implemented to try to determine the best way of removing and replacing parts, he says, "algorithms won't make the same mistakes a human makes. So we have to be aware of the potential for such mistakes. We want to give the design engineers the opportunity to use their knowledge of the domain while doing maintenance-analysis studies."

The biggest challenge the group faces is calculating collision detection and force at the refresh rates required for haptics, approximately 1000 per second. "Imagine trying to calculate the intersection of a 10,000-polygon part with a 100,000-polygon obstacle course in 1/1000 of a second, not to mention calculating the force," says Avila. Because of the practical impossibility of this given the current state of technology, the GE team is building computational models to approximate the force and collision sensations incurred during object manipulation. Just as animators and designers often build lower-resolution visual representations of objects in order to move through large geometric representations, the GE researchers are building low-resolution haptic representations. As with visual displays, says Avila, "we try to keep the detail in places where it's important and lessen it in places where it's not so noticeable." The first step in the process, he says, is determining what the lowest level of acceptable detail is, then modifying the algorithms and data structures to accommodate the predefined haptic constraints.

Handing Out Feedback

The researchers are using SensAble's Phantom force-feedback device. With it, users manipulate a handle, at the tip of which they feel the effect of translation and rotation. "You don't use two hands, and you don't feel forces on your elbow or anywhere else, but you do have this one-grip location that can represent a part or a tool," says researcher Steve Linthicum, who moved to the R&D Center from GE Aircraft Engines to provide first-hand feedback on the system's design. Aircraft engineers can use the haptic device as a wrenching tool, for instance, to analyze wrench access, or it can be used to represent a component on the outside of the engine. Clearly, notes Linthicum, "we're not at the point where you feel all the forces you would feel if you were working on an engine—you don't feel your knuckles hitting on anything and you don't get the tactile feedback of, say, the surface of an actuator on the engine. But you will feel what it feels like when the actuator bumps against geometry."

"Right now, this tool is just another piece of the puzzle to help engineers become more efficient in design development and analysis in the digital environment," says Avila. "The biggest payoff will come down the road in training applications, especially when you're training people on different configurations of the same basic engine. You won't have to keep multiple iterations of certain engines around in a training-school environment. Instead, you'll be able to train users in this visual, haptic, potentially immersive environment, and the students will still get the "hands-on" experience they need."

The industrial-haptics system runs on a standard dual-processor Pentium-class machine (one of the two processors is dedicated to the haptic interaction). The first version will be in the hands of aircraft engineers later this summer. According to Avila, the engineers plan to begin using the system immediately to generate production analyses. This version of the system will be "very useful" on its own, he says, and it will also serve as the first stepping stone to further development. "The engineers will give us feedback about what works for them and what doesn't. We'll learn how they put the system to practical use in a design environment."

Diana Phillips Mahoney is chief technology editor of Computer Graphics World.

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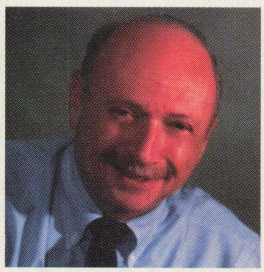
Going Strong

So far, the computer graphics industry is showing impressive activity for 1999. Revenues for this year are an estimated $71.7 billion—up from $63.3 billion in 1998. This forecast includes hardware, software, system, and service revenues from US and non-US suppliers. Represented applications are multimedia (including presentation applications), CAD/CAM/CAE, graphic arts, art, animation, medical and scientific visualization, virtual reality, and real-time simulation.

For the overall computer graphics market, Machover Associates expects a compound annual growth (CAG) of 13% (from $71.7 billion to $133.7 billion) between 1999 and 2004. The 3D segment of those revenues will grow even faster—at a 20% CAG rate, from $24.9 billion in 1999 to $62 billion in 2004. At that time, 3D graphics will represent 46% of the total market, up from about 40% in 1998.

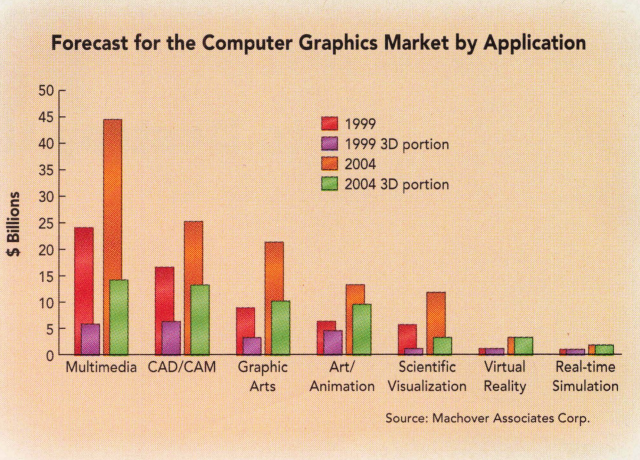
Web graphics, which represents varying portions of each of the aforementioned application's revenues, is one of the fastest growing segments of computer graphics. A year ago in this column, I predicted that less than 2% of 1998's worldwide revenues from computer graphics would come from Internet/intranet applications (July 1998, pg. 18). However, 1998 revenues from Web graphics approached 4%, nearly double my predicted amounts. In the same column, I estimated that less than 5% of the 2003 worldwide revenues would come from Web applications. I now estimate that total Internet/intranet revenues will grow from $4.4 billion in 1999, (already 6% of all 1999 computer graphics revenues) to $11.4 billion in 2004, to account for about 8% of all computer graphics revenues. Moreover, the overall CAG for Web graphics during this period is an estimated 21%, which puts the category just behind 3D graphic arts at 25% and visualization at 22% as the fastest growing segment. Fueling the growth of graphics on the Web is the proliferation of Internet and intranet users. Research firm IDC (Framingham, MA) estimates that by the end of 1999, the US will have about 70 million Web users, a figure that will increase to 136 million by 2002.

The fast-growing 3D segment continues to bolster the computer graphics industry



CARL MACHOVER

Animation also represents a fast-growing sector of the computer graphics industry. A 1998 report by Frost and Sullivan (New York), "US 3D Animation Software Market," states that the total 3D animation software market in 1999 will be $251 million, growing to $414 million in 2004, a CAG of 10.4%.



Multimedia is predicted to remain the highest CG revenue area through the year 2004.

Categories covered in the report include games, broadcast/motion pictures, modeling, corporate applications, training, and Web-page development.

The largest market for 3D animation software in 1997 was video games, which accounted for $57 million of the total $186 million. Video game application sales were closely followed by $54 million in revenues from the broadcast/motion-picture segment. Web-page development ranked third, with revenues of $29 million. The report estimates that revenues for video game 3D animation software will be $80 million in 1999 and will increase to $99 million by 2004. A 1999 Frost and Sullivan report devoted exclusively to the Web animation software market estimates that total worldwide 1998 Web animation software revenues for 2D, 3D, and VRML were $64 million, and are predicted to grow to $142 million by 2005—a CAG of 12.3%.

Finally, traditional scientific and engineering applications—such as CAD/CAM/CAE/CIM and real-time simulation and scientific visualization, which once dominated the computer graphics market—will make up only about 33% of the total revenues in 1999 and decrease to about 29.1% in 2004, though they will still exhibit a CAG of 10.5% over that period. These predictions mirror those I made for these markets in last year's report, and conditions are roughly similar: Science and engineering are now relatively mature markets.

In summation, a healthy computer graphics industry will continue to be bolstered by its fast-growing 3D segment. Animation and video games continue to be an important part of the picture. And Web graphics are definitely an area to watch, as the demand for increasingly sophisticated applications begins to be met by developers overcoming technological hurdles in order to meet that demand.

Carl Machover is president of Machover Associates Corp., a 23-year-old computer graphics consulting firm based in White Plains, New York.

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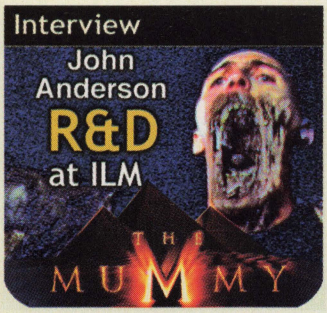

Visual Effects News

Updated: Tuesday June 15, 1999 at 4:50 PM PDT

Lucas Wins Presidio Bid

Director George Lucas has won the rights to develop a $250 million digital arts center in San Francisco's Presidio. The plan calls for a campus-like setting which will house Industrial Light & Magic, Lucas Arts, Lucas Learning, THX and the George Lucas Educational Foundation. The facility will accommodate the companies' approximately 2,500 employees, who are expected to move into their new facilities in 2002.

Tue Jun 15, 1999, 4:50 PM PDT

LightWorks 5.0 Ships

LightWork Design is now shipping version 5.0 of its LightWorks rendering software. LightWorks component software, designed for direct integration into 3D software applications, provides rendering for photorealistic 3D images and animations. The new release features Interactive Image Regeneration (IIR) technology for instant visual feedback on 3D designs.

Tue Jun 15, 1999, 2:45 PM PDT

Jobs News

Dream Quest Images (Simi Valley, CA) is seeking a **Computer Graphic Artist** with a strong working knowledge of 2D and 3D software.

Pixar (Richmond, CA) is seeking a **Production Manager** in the film division with experience in animation production...

Rhythm & Hues Studios (Los Angeles, CA) is seeking a **Database Programmer** with experience in C/C++ and SQL....

Digital Domain (Venice, CA) is seeking a **Windows Programmer** with experience in 2D Graphics...

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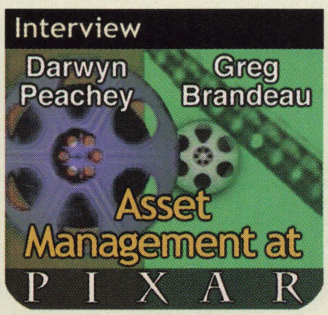

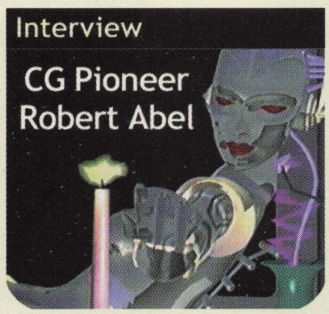

"Godzilla" Team Wins Saturn Award

"Godzilla" captured the award for best visual effects at the Academy of Science Fiction, Fantasy and Horror Films' 25th annual Saturn Awards. The award-winning team includes visual effects supervisors Volker Engelhardt and Patrick Tatopoulos, who won two years ago for Stephen Sommers' "Deep Rising." Godzilla designer and supervisor Patrick Tatopoulos, visual effects supervisor Clay Pinney and associate visual effects supervisor Karen Goulekas. Nominees were announced

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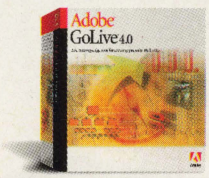

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Workstation Weigh-In

It doesn't take an expert to point out that there have been some changes in the world of 3D graphics workstations during the past few years. Once intended purely for scientific purposes, today's workstations hammer out animated games, movies, and television shows faster than a spinning electron. How did we get here? And which vendors are in the best shape to duke it out in the 3D market?

What set the tone for drastic change in the workstation landscape was the advent of the Windows NT operating system on Intel-based computers in 1994. This emergence of NT-based systems offered a standard that not only brought down prices through the use of commodity components but also opened the door to third-party vendors willing to provide single components, such as graphics cards, rather than entire systems.

Until this point, the traditional Unix vendors had been all things to all people—offering complete, one-stop solutions. Sure, they relied on each other behind closed doors, but the user was not privy to the agreements that put one vendor's graphics subsystem in another vendor's box. Microsoft changed the rules and let us all in on the interconnectedness of graphics computing.

Alas, from 1994 until about mid-1997, the third-party graphics technology available on NT workstations was nowhere near on a par with its Unix brethren. In fact, some would argue it was not even in the same class. So the Unix vendors continued to spin teapots, perhaps every now and then glancing over their shoulders at Intergraph, but not really breaking stride from their own R&D efforts.

Of the workstation vendor heavyweights, which has a winning graphics strategy?

BY KEREN SEYMOUR

It took a sea change in the entire computing market to bring us to the point we're at today, where NT workstations ship many more units than Unix workstations. In fact, NT workstations have elbowed their way into a solid leadership position in the workstation market in just under five years as a result of the enormous, market-defining transitional efforts from a contingent of major vendors, including Hewlett-Packard, IBM, SGI, and Digital, to name a few.

Now that the dust of the last five years has settled and the workstation players are firmly entrenched, the market has been winnowed into three strategic camps:

1. Vendors that invest internally in proprietary, non-OEM graphics (such as SGI and Sun)
2. Vendors that build commodity systems using third-party graphics (such as Dell and Compaq)
3. Vendors that do both (such as Intergraph, HP, and IBM)

Of course, the graphics workstation market also includes many other players, all of whom focus their efforts toward certain niches, such as the Alpha-processor installed base. These vendors also fall into one of the above three categories, but their individual strategies will have little effect on the shape of the graphics workstation market as a whole, given their relatively small market share.

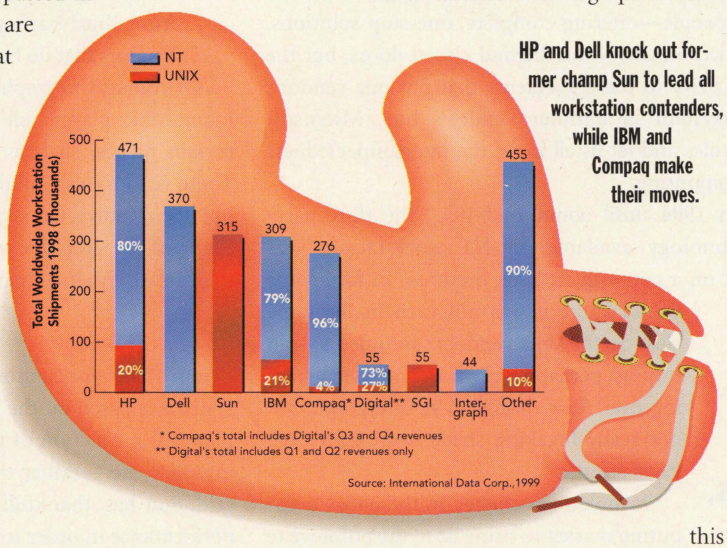
Rolling Their Own

• **Sun:** The workstation-graphics strategy at Sun Microsystems is based on the accepted belief that graphics performance is a function of the entire system—the CPU, the bus interface, etc.—rather than just the graphics processor. This said, Sun has, thankfully, never had to rely on 3D graphics performance in order to be the most successful vendor in the workstation market. Sun's strategy has always been to produce adequate graphics performance for the company's core customers—who tend to be users in large commercial enterprises—but it is content to let others fight it out for graphics-performance leadership.

One can hardly argue with a vendor who has maintained the leadership position in the Unix workstation market for the past seven years. But HP, whose strategy has been to incorporate third-party graphics in some of its NT workstations and internally developed graphics in its Unix systems, surpassed Sun last year as the leader in total market share. Sun may be well advised to consider using third-party graphics, which would enable it to be more competitive by decreasing internal R&D expenses. In fact, the vendor may be heading in that direction. The Ultra 5 workstations today compete head-to-head with NT workstations in the lower end of the market,

that is, with systems costing less than $5000. The graphics subsystem on the Ultra 5 already comprises a third party's board with some Sun engineering integrating it into the system. Yet, because Sun's customers demand a one-stop solution with the promise of absolute integration and certification, the use of third-party components is disguised. This approach could easily be as successful in the Ultra 10 class workstations (which use Sun's own Creator 3D graphics) as well as in some of the company's other systems.

· **SGI**: The most obvious proponent of internally developed graphics is Silicon Graphics, now SGI. The vendor that essentially invented the 3D graphics workstation market is perhaps a victim of its own success. SGI has undoubtedly produced some of the industry's most advanced graphics, continually pushing the high end of the performance spectrum. But such performance comes at a cost. The company's latest market entrants, the NT-based 320 and 540 Visual Workstations, are the result of many years of expensive development. Despite the fact that in today's market they are top performers, they may be surpassed in short order. Indeed, they are architected in a way that precludes graphics upgrades, since SGI, as a means to improve system performance, integrated the graphics right onto the motherboard of its NT systems. In any case, the company is now working harder than its competitors to keep up with the rapid pace of change.



Going Outside

· **Dell** makes no secret about its role in the workstation market as a reseller of third-party commodity components. The company builds relationships with suppliers that it hopes will provide fast turnaround at good price and performance levels. Luckily for Dell, the third-party suppliers these days are meeting expectations. In fact, Dell seems to be charmed in the NT workstation market, moving rapidly into second place behind HP after only a year. Despite a revolving-door policy with graphics partners (first Intergraph, then Evans & Sutherland, then 3Dlabs, now Intergraph and Diamond), Dell's OEM strategy allows the company to react nimbly to changing market requirements without a heavy overhead.

· **Compaq**: Prior to the purchase of Digital Equipment Corp. midway through 1997, Compaq had adopted a "smart shopper" strategy, purchasing third-party graphics to suit users' needs. The addition of Digital gave the vendor a highly accomplished graphics engineering department. In addition, Digital had its own internally developed PowerStorm graphics that, on Alpha processors, blew away the competition. Compaq, however, viewed the investment in graphics as outweighing the benefits and has essentially dismantled Digital's legacy, keeping only the branding strategy. Today's PowerStorm graphics are, in fact, third-party boards. Given Dell's success with a third-party approach, and Compaq's reluctance to invest in the more graphics-intensive segments of the workstation market, focusing instead on the commercial segments, a pure third-party play is probably one of the better decisions that Compaq has made recently.

Mixed Strategies

· **HP**: The largest vendor in the combined NT and Unix workstation market, Hewlett-Packard, has adopted a somewhat complex graphics strategy, but one that gives its customers a wide array of performance options to choose from. HP's Visualize fx Unix graphics offerings, combined with the strong floating-point performance of the PA-RISC architecture, consistently place the vendor among the leaders in 3D benchmarking. The implementation of Visualize fx-6 graphics on HP's Kayak NT workstations introduced at Siggraph '97 set the benchmark for NT graphics performance for almost a year (an eternity in this industry). In addition to using its own internally developed graphics, HP also makes use of third-party products throughout the Kayak NT workstation line. Late last year, however, the management of the Grenoble, Switzerland-based high-end NT workstation, the XW, packed their bags and moved to Ft. Collins—the seat of the Unix workstation team—to align with the Unix graphics strategy of in-house only development. As third-party graphics reaches the performance levels of internally developed graphics, this approach could be too large a cost to bear, particularly since the Visualize graphics are not offered on the open market.

· **IBM's** approach to graphics has historically been to stake one foot in both camps: developing proprietary graphics for its Unix systems and third-party graphics for the NT-based IntelliStations. Long-swirling rumors about porting IBM's

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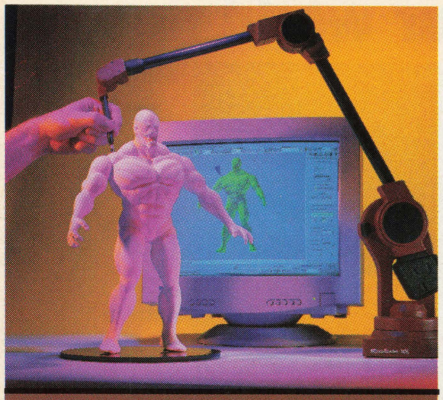

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legacy Unix graphics to NT finally came true this past year in the form of a licensing and development agreement with Diamond Multimedia. The relationship between IBM and Diamond leverages IBM's graphics expertise and Diamond's distribution and marketing dollars, which nicely benefits both vendors. The Diamond FireGL is used on the IntelliStations, in addition to being OEM'd to other vendors, and the PCI version is used for the Unix workstations. In this manner, IBM keeps both the company's Unix- and PHIGs-dependent Catia customers happy, and can participate in the open market with an NT offering. In addition, a cozy relationship with Intergraph gives IBM high-performance Wildcat graphics to round out the high end of its NT workstation line. IBM seems to have found a way to make the best of both worlds affordable.

· **Intergraph's** graphics strategy has undergone a few transitions lately, to say the least. "We're OEM'ing our graphics. No, wait, we're not. Well, OK, just to IBM. Hang on a sec, now we're OEM'ing again, but it's a new company." Hats off, however, to the tenacious little workstation vendor that could, or that is trying to, at least. Not everyone is aware that Intergraph's history is rife with graphics firsts going all the way back to the '60s, when its personable CEO, Jim Meadlock, wrote guidance software for the Saturn moon-launch vehicle that relied on real-time interpretation of spatial data. Since then, the vendor has developed both Unix- and NT-based graphics that have consistently set benchmark records. In recent years, however, Intergraph's graphics fell prey to the same missteps that led to SGI's difficulties: too much performance at too high a cost. Intergraph's answer was to spin off its graphics unit into a separate company, alleviating both high investment costs to the computer company, ICS, and those pesky competitive issues with OEM partners. Intense3D—the new company—now competes for Intergraph's workstation business just as any other merchant board vendor would and does. This raises a new set of competitive issues, but it's better to be competing against one's competitors than one's customers.

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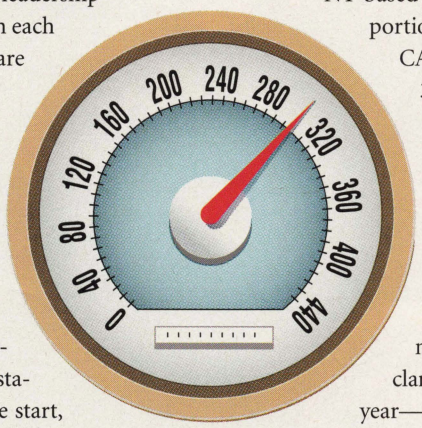
Who's Winning?

Simply pointing to performance or market numbers and proclaiming a winner doesn't tell the whole story. All suppliers with 3D graphics systems can claim leadership on one benchmark or another. But within each of the three strategic approaches there are certainly vendors that stand out.



Between SGI and Sun, the two companies that still exclusively develop their own graphics but do not currently participate in the open market, SGI is the clear 3D performance and market winner. But this is a hollow victory for the once high-flying, but now embattled vendor. The company's "only-invented-here" approach to the NT workstation market has not only given SGI a late start, but will ensure that it remains constantly struggling to keep up with the pace of competitors. And despite the fact that the InfiniteReality graphics on the vendor's Onyx Unix workstations delivers stunning performance, SGI's lackluster financial performance over recent years has slowly eroded user confidence in its strength as a Unix workstation supplier.

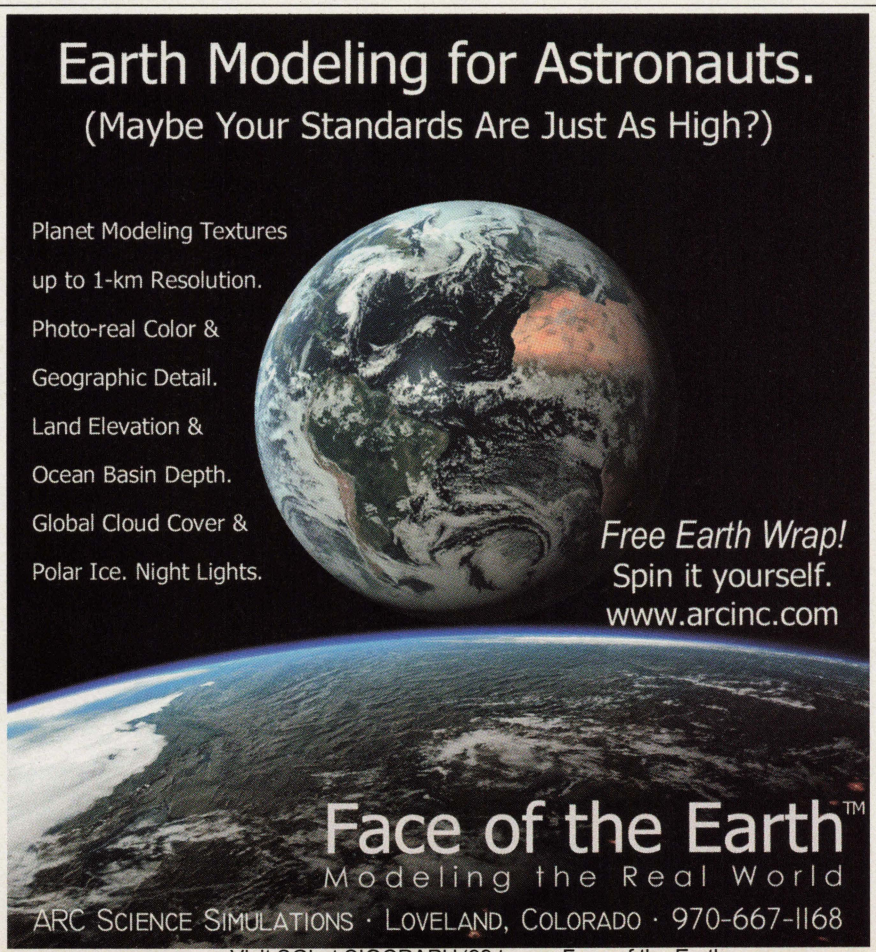
Among the vendors that rely solely on third-party components, there's no question about who deserves top honors. Dell Computer has made astonishing strides toward market-share leadership in the short time that the vendor has participated in the market. With no apologies for its aggressive strategy of entering markets well after they have been carved out by the heat-seeking leaders, Dell should be congratulated for its vision and understanding of the user community. The company's ability to react to user needs by employing new graphics options as they hit the market has catapulted it into second place in the workstation market.

The winner of the mixed-strategy approach, utilizing both internally developed graphics and third-party components, is a little harder to identify. I'd like to hand the trophy to Intergraph because without the vision in 1994 that initiated its efforts in the digital content creation space, the NT market would not exist in its current strong state today. But a winning strategy has to be complemented by market-share leadership, and, in that regard, HP deserves top honors.

However, it's IBM who has, in the last year, focused on its core competencies in the workstation market, and developed a graphics strategy that has resulted in growing market share momentum for both its Unix- and NT-based workstations. And given that a large portion of IBM's core customers are in the CAD and CAE markets and dependent on 3D performance, for IBM, graphics leadership truly does translate into market leadership.

Since a small number of suppliers (compared to the PC market, for instance) determine the direction of the graphics-workstation market, the strategies of the key players allow us, as market observers, to say with relative clarity what the future—or at least the next year—will bring. The growing use of third-party graphics will drive 3D workstation performance up and prices down faster than if the use of internally developed graphics was growing. And that's good news for buyers and sellers alike.

Keren Seymour, former workstation analyst at IDC, is now a partner at Be Cause PR & Analyst Relations. She can be reached at keren.seymour@becausepr.com.



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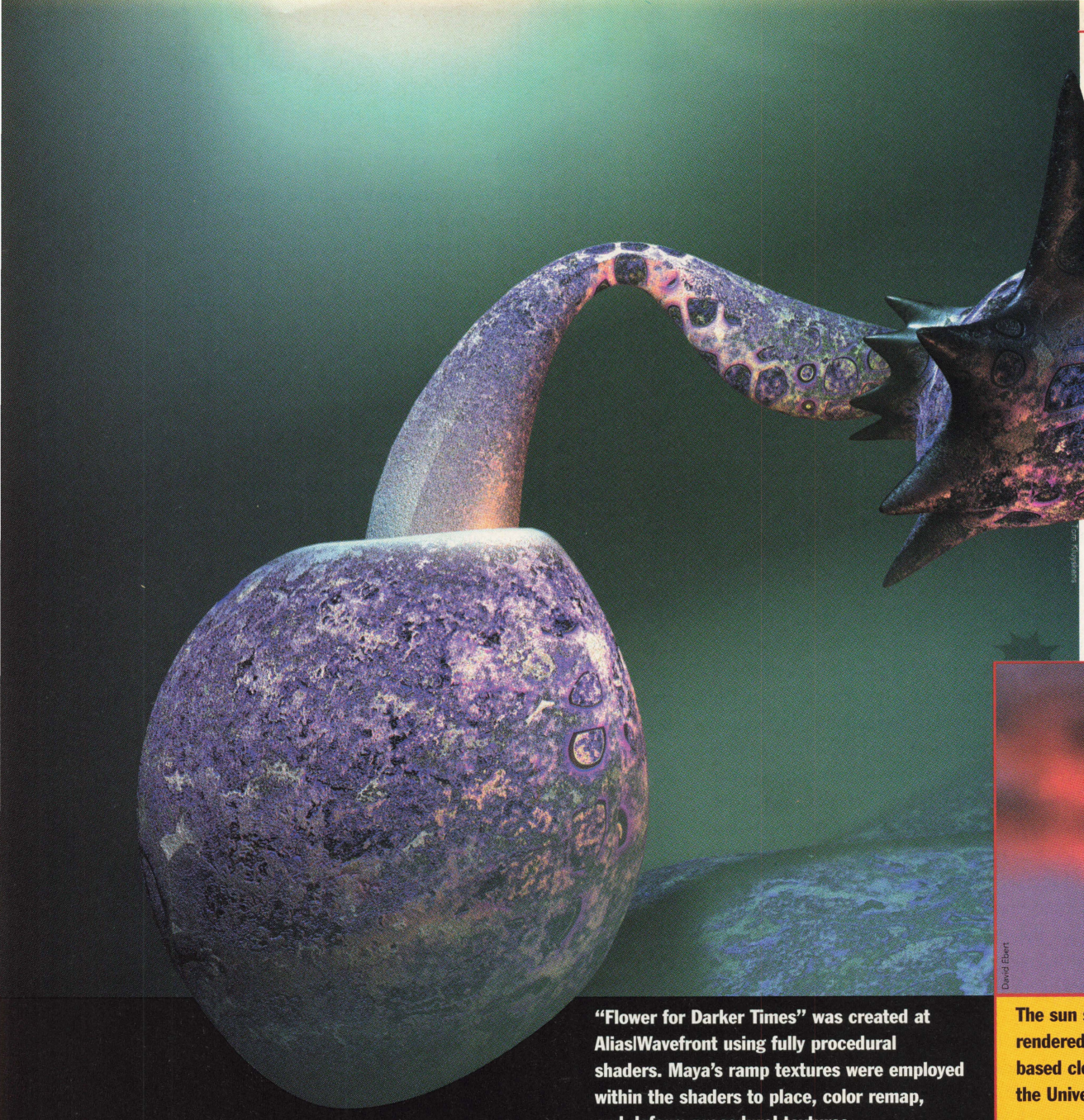


"Flower for Darker Times" was created at Alias|Wavefront using fully procedural shaders. Maya's ramp textures were employed within the shaders to place, color remap, and deform procedural textures.

The sun sets on volume rendered, implicit-surface-based clouds created at the University of Maryland.

BY DIANA PHILLIPS MAHONEY

powerful procedures

MATH-BASED TECHNIQUES FOR GENERATING COMPLEX IMAGES AND ANIMATIONS ADD UP TO A NEW 3D EXPERIENCE FOR MODELERS AND ANIMATORS

Rules to follow, procedures to implement. In the world at large, these are the bane of the free spirit's existence. In the world of computer graphics, they are the wings on which the free spirit soars.

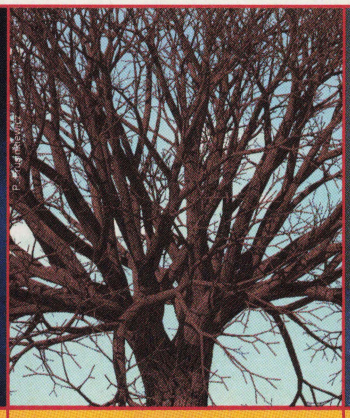
Rules and procedures are at the heart of a visualization approach called procedural image generation, in which a small number of simple mathematical expressions drives the creation of stunningly complex graphics that would often be impossible, or at least incredibly painful, to create with traditional CG techniques. Examples include re-creating natural phenomena and environmental effects such as flowing water or raging flames, ascribing realistic motion to characters, modeling the behavior of objects in a group (flocks, crowds), and simulating the physical interaction of multiple objects.

Procedural graphics is actually an umbrella term covering a range of rules-based visualization approaches. It encompasses such technologies as behavioral animation, physically based modeling, dynamic L-systems (for branching simulations), particle systems, and implicit surfaces (metaballs). The common thread that runs through each of these technologies is the reliance on simple mathematical expressions to create complex structures or movement. through the waves of the water. There's the collision of the object with the water, but there's also the impact of the collision—a splash, water spray, the residual wake," says Paul Salvini, director of research and development at Side Effects Software (Toronto). Re-creating such an effect with traditional tools could be excruciating. With a procedural architecture, however, "you can set it up so that the computer, on a frame-by-frame basis, automatically calculates the intersection of the water surface with the hull and generates realistic spray and wave effects. That's incredibly valuable in terms of production time and image realism."

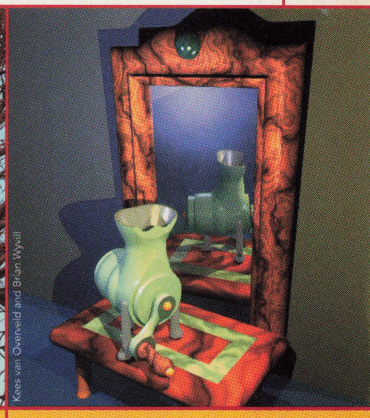
"Procedural techniques exploit computers for what they're good at—crunching numbers—and they unburden users from the detail specification, freeing them to more fully explore and express their creativity," says David Ebert, computer science professor at the University of Maryland at Baltimore County (UMBC) and co-author of *Texturing and Modeling: A Procedural Approach* (1998).

When it comes to procedural modeling and animation, Ebert's head has been in the clouds, literally, for a number of years. His research efforts have focused on procedurally modeling and animating volumetric clouds and other gaseous phenomena, such as smoke and fog. While traditional modeling

Thanks to a volume-based procedural graphics plug-in for Alias|Wavefront's Maya, an angel floats in a cloud within an image created by students at the University of Maryland.



Dynamic L-systems makes it possible to simulate the branching of a tree created at the University of Calgary.



Implicit surfaces and constructive solid geometry (CSG) combine to create smooth, buildable models.

The primary appeal of proceduralism in all its guises is that it enables modelers and animators to focus on the big picture—the end result—by letting users describe and control how they want objects in a scene to look and behave, and directing the computer to make it happen. The "big picture" could be any complex model or dynamic system. It could be the spray from a waterfall, a crowd at a ball game, or the operation of pistons in an engine.

"Regardless of the application, procedural techniques enable ever-increasing complexity with minimal effort," says Chris Ford, an application engineer at Alias|Wavefront (Toronto). In character animation, for example, "users don't have to explicitly save every joint and muscle position of a skeleton. To animate the character, they can set up everything procedurally beforehand so the muscles and other structures function automatically according to predefined parameters for arm and leg movements."

Object collision is another example. "Imagine a boat crashing and animation tools are ill-equipped to create realistic visualizations of such effects because of their computational intensity, procedural systems are ideally suited to the task. To animate clouds procedurally, for example, a user might set up parameters for such factors as pressure gradient, particulate density, and humidity, and encapsulate these into interactive controls for manipulating the clouds' aesthetic characteristics, such as their puffiness or wispiness. By manipulating these controls, perhaps in the form of sliders, the user automatically sets into motion the chain of events that are needed to effect the desired change. For example, to make a cloud puffier, the user would move one slider that controls all the factors contributing to puffiness, rather than changing individual characteristics such as the humidity and density values.

Such control, says Ebert, "lets animators and designers focus on their art rather than be constrained by the underlying technology."

Old Idea, New Story

The use of procedural techniques to create digital effects in such high-profile projects as *Titanic* and *A Bug's Life* has made proceduralism a hot topic within the computer graphics community. Yet these tools are not new. Computer scientists have been toiling for more than two decades to develop efficient mathematical expressions for driving modeling, texturing, and animation. Commercially, the technology made its first appearance nearly 12 years ago in the Prisms product from Side Effects Software. Within the past few years, many major 3D modeling and animation vendors have jumped on the procedural bandwagon. For example, Side Effects' Houdini (the successor to Prisms), Alias|Wavefront's Maya, Avid's (Tewksbury, MA) Softimage 3D (and soon its Sumatra product), and Discreet's (Montreal) 3D Studio Max (formerly a Kinetix product) are all built, to various degrees, on a procedural paradigm. On the engineering side, some of the leading CAD vendors have begun incorporating procedural capabilities as well (see "CAD On Its Best Behavior," page 36).

What is new, however, is that proceduralism has become mainstream. And the now-widespread commercial availability of these tools is having a huge impact on computer graphics, both in terms of the images being produced and the production processes themselves. Perhaps the most significant consequence has been the disintegration of what were once clearly defined boundaries between modeling, texturing, and animation. Not only can procedural tools be used to drive each of these aspects of the design process independently, they can serve as a bridge linking various steps together, with the end result being a streamlined production process and a medium for reaching new creative heights.

"Once you start working procedurally, modeling, texturing, and animation often overlap to create the final image. Textures can greatly enhance the modeling or animation, animation can influence textures, and textures themselves can be animated," says Tom Kluyskens, an application engineer at Alias|Wavefront and the artist who "grew" this month's cover image using procedurally animated textures. A growing plant, for example, "can be a pain to model and animate [traditionally]," he says. In contrast, a procedurally animated texture is simple to set up and computationally efficient to implement. The animated texture can be applied to the transparent surface of an object, and it can be programmed to "detect" the presence of adjacent objects and thus change its appearance accordingly. Additionally, procedures can be used to define a transparency map that acts only on the visible borders of an object, enabling the simulation of significant detail while maintaining a low object tessellation count for rendering efficiency.

Such procedurally animated textures are particularly useful for the visualization of scientific concepts such as velocity, acceleration, turbulence, friction, and acidity, says Kluyskens. "It's very easy to procedurally link the speed of an object with its color, for example, or to animate its transparency when it is inside another object."

According to Kluyskens, procedural animation and texturing fundamentally oppose direct keyframe animation and the use of painted or photographed texture files. "[With procedural tools] the user does not control the exact position or color, but rather controls a motion concept and the characteristics of a material. The machine performs the motion and coloring; the user controls the 'look.'"

The shift of low-level control from the user to the computer for modeling, texturing, and animation tasks has led to a welcome breakdown in the traditional linear workflow of animation production, says Alias|Wavefront's Ford. "The traditional way animators have worked is to first create a model, then set up the dynamic effects, then take that data and plug it into the renderer. If what comes out at the other end isn't right, the user has to go back to the beginning and change the model, change the dynamics, and so forth."

In contrast, a user can set up a procedure to generate an "event-driven" animation through which various situations trigger specific events. For example, when an animated river-flow encounters a large rock in its path, the flow will detect the rock and automatically divert around it, and the diversion will then trigger a change in the water surface at that point (from smooth-flowing to foamy, for example), which will drive subsequent events. "If it's not right, the user can go back and modify the basic procedure, and the procedure will itself modify the other procedures that are dependent on it. This means the user doesn't have to explicitly, linearly, edit each and every stage in the process," says Ford. Such flexibility, he says, goes a long way toward fostering

To efficiently render thousands of procedural wildflowers, University of Calgary researchers used a system developed with Stanford University called approximate instancing, through which groups of plants are replaced by representative objects before the scene is rendered.

The "Cabrets Murex" by Callum Galbraith was built with the University of Calgary's Blob Tree software.

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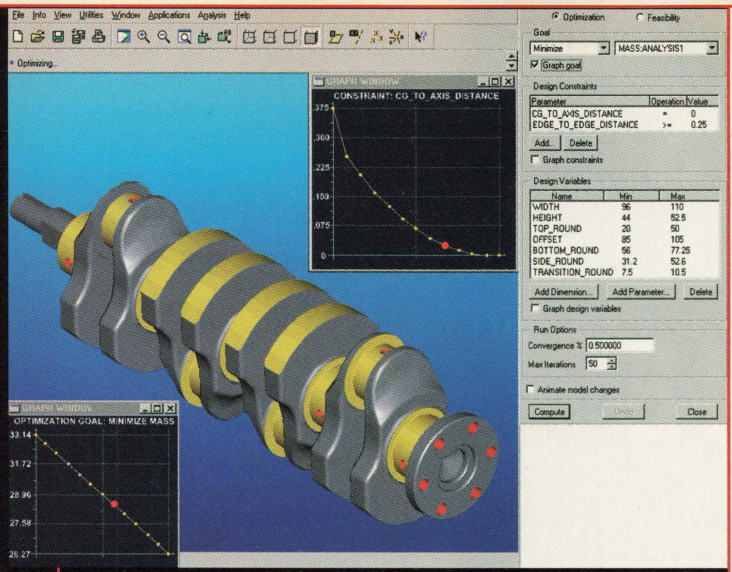


The behavioral capabilities in PTC's Pro/E 2000i automatically generate product iterations based on predefined specs for such factors as material properties, cost, and performance.

CAD ON ITS BEST BEHAVIOR

While entertainment applications of procedural graphics tend to monopolize the technology's limelight, there's growing interest in the development of procedural systems for streamlining and enhancing traditional CAD processes. The objective for such development in the engineering arena, however, is not so much to improve the aesthetic of a CAD model, but to improve the engineering of it—to create a higher quality product in less time, at less cost.

To this end, some of the major CAD vendors have been exploring ways to incorporate various degrees of proceduralism into their product lines. Parametric Technology Corp. (PTC; Waltham, MA) is the first to embrace the technology wholeheartedly. The latest addition to the company's ProEngineer product line, Pro/E 2000i, embeds behavioral capabilities directly into its modeling kernel. With these abilities, users are able to create an object or objects, then direct the computer to generate the best model based on predefined constraints for such factors as material properties, production costs, and performance considerations.

Typically, to get such information, engineers have to generate multiple iterations of their models manually, and even then they can only get close to their desired result. With behavioralism, says Dan Storr of PTC, "the designer still has to set up the problem and understand it, but the system condenses the process with automatic iterations. And instead of just getting 'close' to the ideal product, the system lets the designer reach that ideal product, and it does it in a fraction of the time."

The software also lets users create behavioral features for automatically accessing external applications, such as structural analysis data, during the iteration cycle. And a patent-pending "shrink-wrap" tool lets users generate an external representation of their model and, with behavioral modeling, apply kinematic mechanism joints (hinges, welds) to drive functional simulations.

designers' creativity, since it frees them from time-consuming, back-to-scratch revisions.

Jim Rutherford, a senior animator with the Hollywood-based Toybox production house, agrees. As an example, he describes his development of a particularly complex model—a two-headed lizard—for the David Cronenberg film *eXistenZ*. The model had to be extremely detailed to match a latex animatronic of the creature that would cut in and out of the scene, and it had to be flexible enough to allow for a wide range of motion and secondary animation. Rutherford created the creature procedurally with Houdini. To do this, he first created a rough version of the reptile from a digitized cast of the puppet and began developing a walk cycle.

"The walk evolved through several iterations because the client wasn't sure how a mutant frog-legged lizard would walk. I was constantly changing the inverse kinematics setup, and this meant I needed to change the way I built the creature so its body would accommodate the different movements," he says. With Houdini, Rutherford was able to move back and forth as needed so that the modeling and animation grew off of each other. "I like to joke that I didn't force a walk cycle on the creature. The creature told me how it wanted to walk, and I just let it go."

Texturing the two-headed lizard drove the process in the same way, says Rutherford. "There were times that I had to change the model so the textures would live properly on the surfaces, both in the static state and as it animated." And while it may sound like a complicated workflow, Rutherford stresses that the procedural tool set allows for such fluidity and much more. "I was getting last-minute requests to change textures and to build in a lot of secondary animation, like tendons popping out and jiggling in the skin of the neck when the leg moved a certain way. And in the last couple weeks of the project, I had to change fairly dramatically a very complicated path where the creature ran across the ground and scampered up the side of a gas pump." Because the creature was procedurally modeled and animated, the animator says, he was able to go in and quickly adjust the underlying parameters to achieve the desired effect.

Since creating the lizard, Rutherford has been experimenting

CAD is also on the minds of procedural graphics researchers. At the University of Calgary, Brian Wyvill is developing methods for using implicit surfaces in engineering applications. He and his colleagues are investigating the use of constructive solid geometry (CSG) in conjunction with implicit modeling techniques. With implicit surfaces, it's easy to generate curved surfaces through automatic warping and blending, which are notoriously difficult to achieve with parametrics-based curved surfaces, says Wyvill. Constructive solid geometry offers the advantages of classic Boolean operations, such as unions and intersections, to combine simple primitives, which may also be warped and blended using a custom data structure called the Blob Tree.

with building other fully procedural creatures using what he calls a "backward" development approach. "A truly organic structure redefines its surface constantly as it moves based on its underlying bones, muscles, tendons, veins, and skin. My theory is that you will never successfully get truly naturalistic movement by building the perfect model and then trying to deform it later," he says. Thus, Rutherford builds the inverse kinematics bone structure of his characters first, then attaches fully animatible muscle shapes, or surface generators, to the bones. "Curves are [procedurally] generated from the points on these muscle shapes and skinned as it animates. It rebuilds on every frame, and because the underlying curves are based on the animating generators, you get a lot of interesting secondary surfaces and deformation."

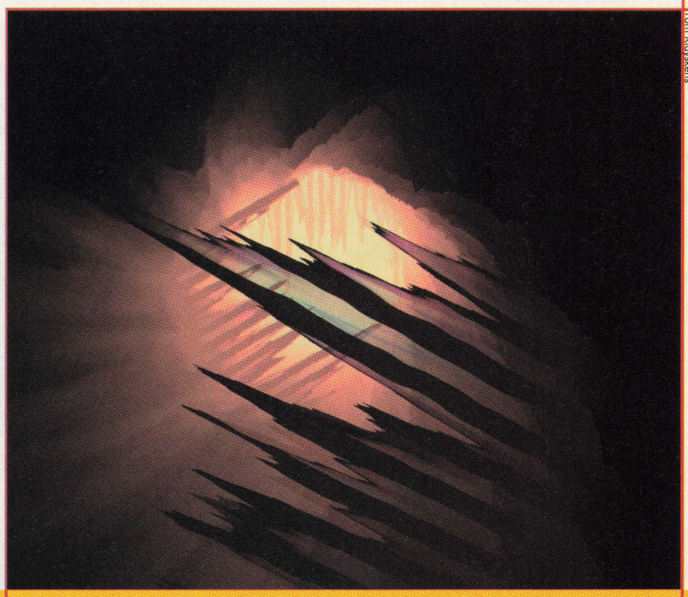
A similar technique was used by animators with SquareSoft (Redwood City, CA) in the development of the "blobby creature" for the game *Parasite Eve*. According to the story line, the gelatinous creature was to storm through the streets of New York, dripping pieces of itself onto the pavement. To achieve this, the animators had to build a model that could change its shape over time. They built the creature with Houdini using a motion-capture skeleton, the bones of which were represented by metaball-laden splines. They set up the software to automatically generate all the secondary animation, such as the swinging and jiggling of the gooey substance. An added benefit of this approach was that once the form and motion parameters for the creature had been defined, the animators were able to reuse the creature in multiple shots.

Taking It To the Next Level

As modelers and animators are becoming more proficient in the application of procedural tools, they're clamoring for even higher-level controls, and the vendors are responding in kind. The latest version of Houdini, for example, includes interactive procedural tools that allow animators to work with motion—record it, blend it, combine it, layer it, and choreograph it—in real time. "This is very important for animators. We've seen the results of bad character animation over time, and what happens when you have to keyframe and work with characters in a non-real-time way. You can't quite see how they're going to walk and move, and you can't get the subtleties of the animation right despite much time and effort," says Side Effects' Salvini. "By providing tools for puppeteering and gesture-capturing in real time, we're going to end up with far more realistic results."

At Alias|Wavefront, the latest addition to the Maya tool kit, called Maya Paint Effects, is also expected to up the ante in terms of the scene realism it can generate. In the software, procedures are defined in the rendering part of the system to control the creation and behavior of incredibly dense amounts of material—a field of wildflowers, for instance, or a thick forest—with minimal geometry to burden computer processing capacity.

And the soon-to-be-released Sumatra from Avid/Softimage promises to include higher-level controls for encoding characters with behavior. "In Softimage 3D, we provided all the nuts and bolts for encoding intelligence into models," says Marc Petit, direct of technology at Softimage. "In Sumatra, we'll be taking



Tom Kluyskens

"Faked fog" and transparency mapping with procedural shaders provide the color in this image created at Alias|Wavefront. The scene contains no lights and no file textures.

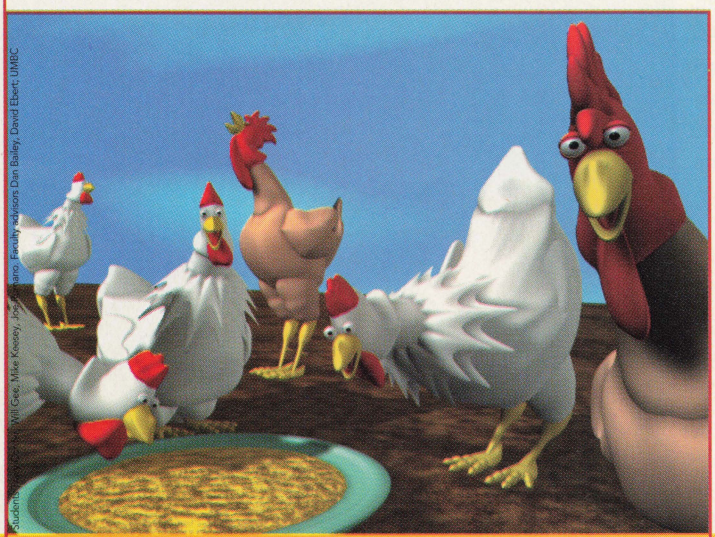
A number of obstacles must be overcome before such a system could be implemented practically, says Wyvill. One is the long rendering time for implicit surfaces. But as hardware speed increases and algorithms become more complex, this will become less of an issue. Accuracy is another consideration. "Engineers want to know precisely where a surface is and what the precision of the surface is. There's still a gap between what we're doing and the development of real engineering surfaces," he says.

The CSG/implicit modeling system may soon fit the bill for less-demanding CAD applications, such as product design. The benefit of the implicit models in such an application, he says, is that it's easy to gather such information as the contact between surfaces and how surfaces react, which are difficult tasks in traditional computer graphics. "Imagine you have a piece of clay. You might want to deform that clay according to how it's interacting with another object. If you model something with polygons, you might know where the vertices of the polygons are, but you'd have to do some fairly lengthy calculations to determine whether two polygons are intersecting. If you've got 1 million polygons on one object and 1 million on another, it's computationally prohibitive to test them against each other."

As proceduralism continues to come to the forefront of computer graphics, it will inevitably have a considerable impact on CAD, says Paul Salvini, director of R&D for Side Effects Software. "Procedural modeling is perfect for users who are trying to visualize complex datasets. They can hook up data, view it, manipulate it, and try to find the best way to make something happen. It's just a matter of putting the tools in a package that [engineers] feel comfortable using." —*DM*

this a step higher, by abstracting the underlying controls. It will allow people to deal with a character without knowing or understanding the internal structure."

The ability to abstract the control of underlying details in such a way is critical to the commercial success of procedural technology, according to David Ebert. "There's no limit to what you can get a system to do when you create an algorithm, but the question is, how do you make it directable? How do you allow higher-level control and better direction without the animator needing to know what you're doing underneath?" To be useful to a broad user base, commercial tools have to be able to encapsulate a wide range of controls into intuitive options, but also be flexible enough to allow users to control the details when necessary. "In the case of [procedurally generated] clouds, for example, do you want an animator to have to stick in things like stagnation pressure and particulate density, or do you want to give them sliders for things like puffiness?" The latter option simplifies the tool, but the ability to move back and forth between the two puts the control of the end product in the hands of the user.



Students: Jason Bickerstaff, Will Cree, Mike Keesey, Josh Leano; Faculty Advisors Dan Bailey, David Ebert; UMBC

The behavior of autonomous chickens is based on the seven deadly sins in a procedural simulation by University of Maryland animation students.

Technology Transfer

While software vendors grapple with the best way to harness and package the power of proceduralism, they're also keeping close tabs on the academic and corporate computer graphics labs, where researchers are turning out increasingly complex procedural algorithms. "The speed at which new developments in this area make it into the industry is incredible," says Brian Wyvill, a computer graphics researcher at the University of Calgary. "Typically, a whole bunch of new ideas are published at Siggraph, and within a few months, those ideas are out there being used in animation. I don't know of any other industry where technology transfer happens so quickly."

Vendors are accelerating this technology transfer by partnering with researchers, both formally and informally. For example, Side Effects Software has been actively involved for a number of years with CG researchers at the University of Waterloo. The two groups meet regularly to share ideas, and much of Side Effects' own research and development team are alumni of the university's computer graphics program.

Similarly, Alias|Wavefront is "always open to technology relationships with academia," according to Ford. "Obviously, we can't invent everything from scratch, so we keep an eye on people developing cutting-edge techniques and often use those as the basis for new tools." An example is the material-simulation tool for Maya called Maya Cloth. "It's not a secret that Cloth is based on the work done by David Baraff and Andrew Witkin [of Carnegie Melon University]. We held exclusive rights to a Siggraph paper they published last year."

Because procedural techniques offer such tremendous potential for achieving unmatched levels of realism and detail, there's no shortage of technology ideas to "poach" from the labs. At the University of Calgary, for example, Wyvill and his colleagues are experimenting with a procedural approach for rendering soft shadows (shadows created by area sources). Soft-shadow calculation is a computationally intensive task, particularly when the occluding objects have complex geometry. The Calgary team's procedural approach builds off the group's work modeling and texturing implicit objects—3D contours represented by scalar fields in which every point in space has a value.

"It occurred to me that it would be a good idea to use these scalar fields for other purposes than just building the model. For example, for rendering penumbra [the lighter shadow effect caused where a point is partially visible to a wide light source," says Wyvill. "A cone-shaped procedural primitive can return values representing shadow density relative to a particular light source. By passing in the point whose shadow density you want, it is possible to get a reasonable result without having to send off millions of rays [raytracing] to sample around a wide light source." This approach results in a substantial time savings over raytracing, says Wyvill.

Some of Wyvill's colleagues in the university's Computer Graphics Research Lab, in conjunction with researchers at Stanford University, are also pushing the procedural envelope. They're developing tools to tackle one of the most daunting CG challenges that exists: nature. Leading this effort is Przemek Prusinkiewicz, a pioneer in the development of tools for simulating complex organic structures. Currently, Prusinkiewicz's efforts are focused on modeling and rendering entire plant ecosystems—dense scenes comprising thousands of plants. "If there are three to five plants in a scene, the user can grab individual plants and place them by hand. If you have a forest or an entire meadow, it's necessary to do it procedurally," he says.

Doing this requires modeling the terrain, then distributing geometric models of individual plants throughout it, taking into account how the plants would interact with one another and with the environment. This can be done by procedurally using L-systems to simulate the processes through which different plants are distributed over space based on such criteria as density and the proximity of water. Although the algorithms exist to cultivate such scenes, the challenge researchers face is the geometric complexity of the images. "The numbers of polygons in these scenes are orders of magnitude larger than anywhere else," says Prusinkiewicz. Thus, efficiently rendering such scenes, which can

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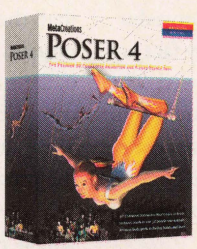

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consist of billions of primitives, is impossible with traditional tools. Consequently, the researchers have developed a system that reduces the geometric complexity of scenes comprising parameterized procedural models of individual plants using a technique called approximate instancing, whereby similar plants, groups of plants, or plant organs are replaced by instances of representative objects before the scene is rendered.

The list of possible applications of procedural image generation is endless. A project Ebert and Dan Bailey from UMBC's Visual Arts department assigned to students in a class they cotaught last semester provides a window into the future of proceduralism. They challenged students to extend the procedural capabilities of Alias|Wavefront's Maya software. One student created an "autonomous chicken farm," in which chickens were articulated with autonomous personalities based on the seven deadly sins. Procedures controlled their movement and how they interacted with the other chickens in their environment. Another student developed a method for procedurally generating cave interiors. And yet another sought to pull out higher structures from a musical input stream, picking out characteristics that an animator could use to control a character based on the type of music. "The idea was that the character could be made to rumba or do something else automatically, without the animator having to work at a low level," says Ebert.

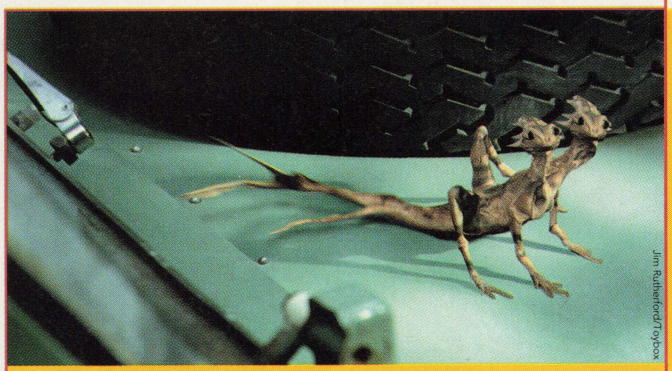
On the commercial horizon for procedural tools are a number of advances. "We're already at the point where we can give complex behaviors to characters and interact with those characters. The next step is to allow animators to create smart characters that understand their environment and the context in which they appear, so they can sit, stand, walk, even interact with other characters in the scene," says Side Effects' Salvini. "We want the characters to have an emotional component, too. They'll be able to exhibit the characteristics of being happy or sad, which you'll be able to discern by the subtleties of how their bodies move, their energy level."

Softimage is also interested in enabling smart characters by hard-coding human behavior into a skeleton. The company is also developing techniques for advanced motion blending. "We want to be able to link any motion clip to any object and blend the motion using analysis data so the object behaves appropriately," says Softimage's Petit.

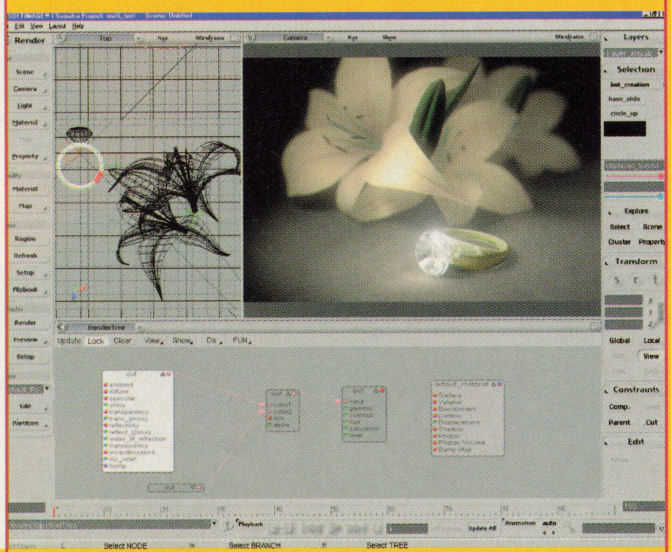
Alias|Wavefront is focusing on the development of sophisticated procedural animation techniques that the user won't have to explicitly set up from scratch, says Ford. "They'll be able to access the function from the menu, and that function will trigger a series of internal events inside Maya."

Also under development, but perhaps further down the line, are hardware-based procedural capabilities. "People are definitely starting to implement some of these techniques, like procedural textures, in hardware," says Ebert. "The challenges they face are the complexity and the types of operators that are allowed. The questions that come into play when you build something into hardware is, what kind of control do you have, and how flexible can you make it." The key, he believes, is the development of good parameters and the availability of "hooks" to adjust them, since a hardware-implemented algorithm can't be changed.

As procedural tools continue to proliferate, it's likely that they will begin to see application in every aspect of image generation, according to Ebert. "Once you are used to using [procedures] for one activity, using it for others is natural."



One of the stars of the David Cronenberg film *eXistenZ*, this two-headed lizard was procedurally modeled, textured, and animated in Houdini.

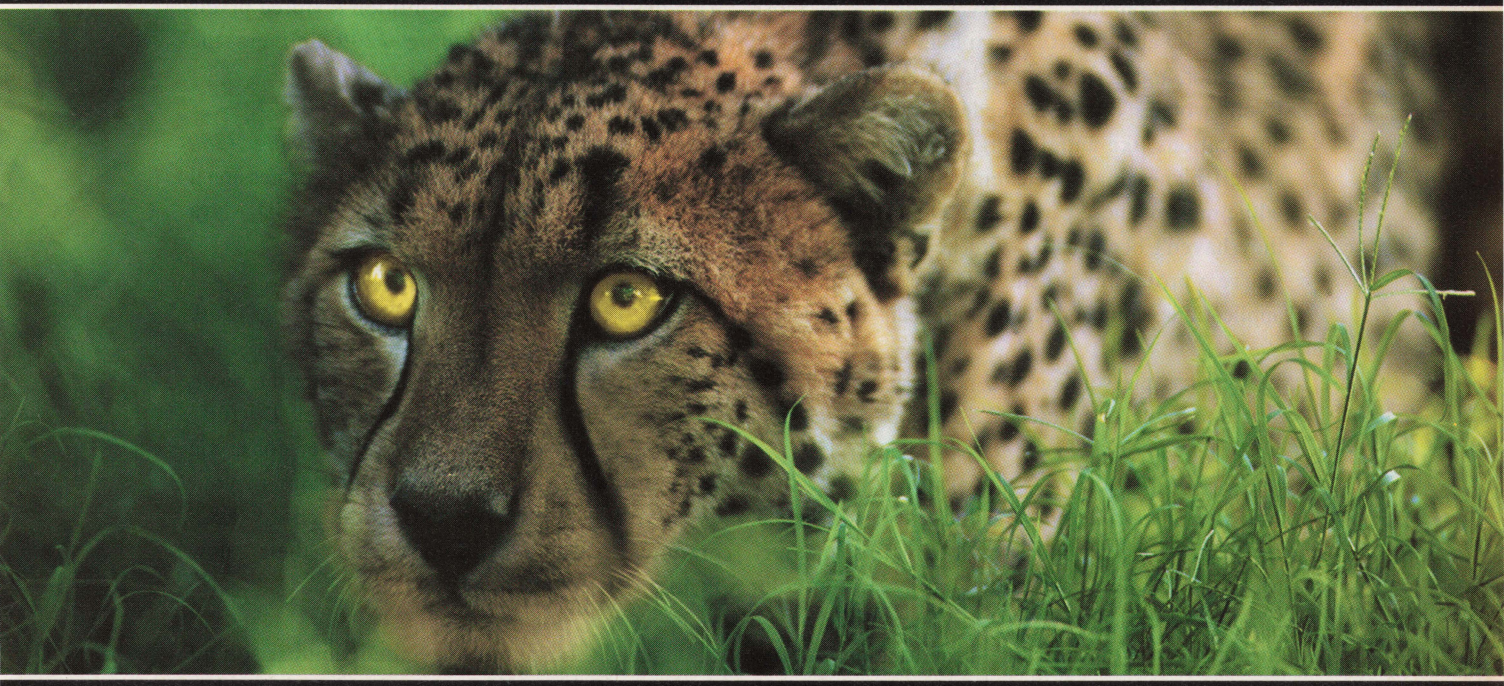


This interface from a beta version of Avid/Softimage's soon-to-be-released Sumatra, the successor to Softimage 3D, illustrates the advanced procedural capabilities the program will offer.

Toybox's Rutherford believes every animation project can benefit in some way from a procedural approach. While a procedural framework can at times be difficult to set up depending on the nature of the control parameters being implemented, he says, "you are generally rewarded in the end, especially if you want to reuse the workflow on future jobs." He warns, however, that the perceived power of procedures can have a negative impact. "I know many animators who will spend days trying to make something fully procedural or animate it with horribly complicated expressions, when they could have just pulled a few points and set a few keyframes. But that's not [a problem with] the program. That's the animator."

Diana Phillips Mahoney is chief technology editor of Computer Graphics World.

Who says we're not looking forward to Merced coming out?



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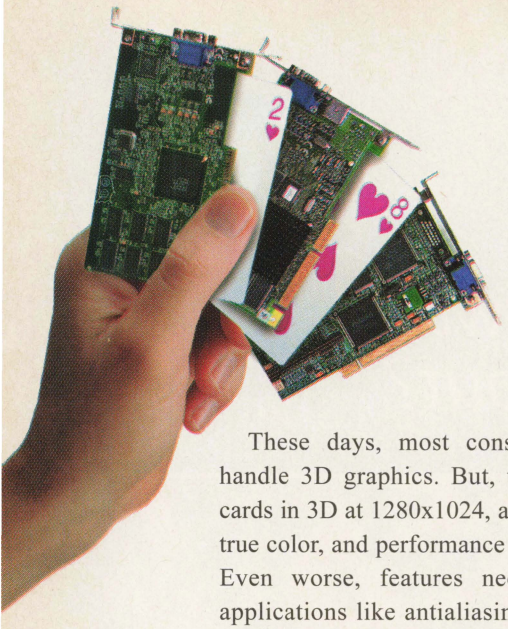

Cards for play.

These days, most consumer-level cards can handle 3D graphics. But, try using one of those cards in 3D at 1280x1024, at a high refresh rate and true color, and performance plummets dramatically. Even worse, features needed for professional applications like antialiasing, alpha blending, and stencil planes may not even be supported. And, while most of these cards claim OpenGL readiness, they haven't been tested with key applications. If you're a professional using 3D CAD or animation applications, you need a card that means business.

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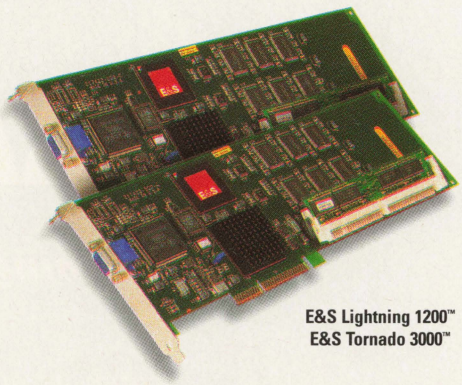

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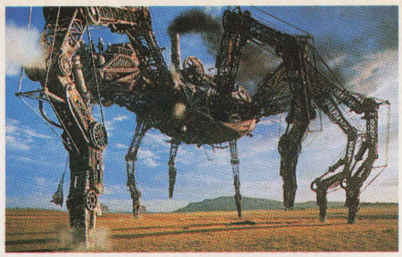
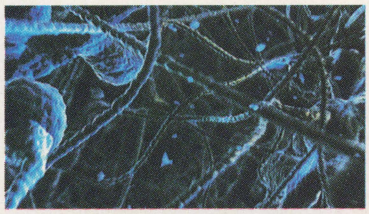
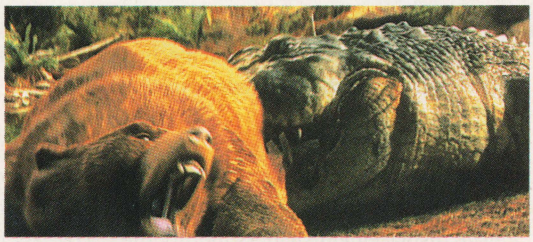
summer heat

THE SUMMER'S MOVIES SHOWCASE SOME HOT TRENDS IN VISUAL EFFECTS







This year, we've selected five feature films and one short animation for our summer movie review that represent some current trends in visual effects. In *Wild Wild West,* the CG star is a machine—a hard-surface model, as are the droids in *Star Wars Episode I*—but in a Jules Verne, rather than modern or space-age, style. In *Wild Wild West* and in *Inspector Gadget,* we see digital humans as stunt people and human stars fitted with digital prosthetics, something we saw earlier this year in *The Mummy* (see May 1999, page 34). That movie showed us what a brain might look like bouncing around inside the skull of a walking skeleton, while *Fight Club,* scheduled to open later this summer, sends us inside a human brain, in a fly-through that is as photorealistic and scientifically accurate as possible.

Interestingly, artists at Digital Domain used the same rule-based procedures, called L-systems, to grow the tree in *What Dreams May Come* (which won the 1999 Oscar for visual effects), and to grow the structures inside the brain for *Fight Club.* Increasingly, the more natural the effect, the more likely it is for artists to use algorithms to help them create complexity, whether visual or kinetic (See *Powerful Procedures,* pg. 32). Hair, fur, feathers, smoke, steam, vapor, dust, sand, and so forth are typically created procedurally, often with the help of particle systems. Procedural shaders that were written in Pixar's (Pt.

BY BARBARA ROBERTSON

WILD WILD WEST

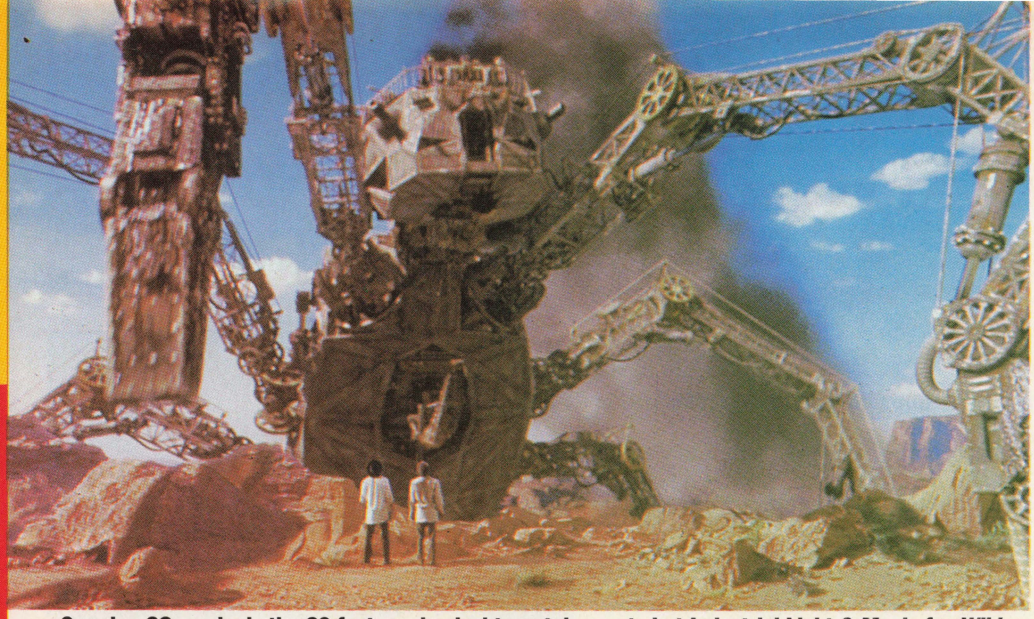
FIGHT CLUB

LAKE PLACID

INSPECTOR GADGET

FISHING

THE PHANTOM MENACE



Spewing CG smoke is the 80-foot mechanical tarantula created at Industrial Light & Magic for *Wild Wild West*. Notice the hundreds of moving parts.

Wild Wild West

Directed by Barry Sonnenfeld of *Men in Black* fame, Warner Bros.' *Wild Wild West* stars Will Smith as James West and Kevin Kline as Artemus Gordon, two government agents who must save President Grant from the evil, and legless, Dr. Arliss Loveless (Kenneth Branagh). Despite mixed reviews, the movie shot to number one at the box office over the July 4 weekend. Based on the 1960s television program, the film mimics the series' use of quirky gadgets by offering a few of its own, created largely at ILM under the direction of visual-effects supervisor Eric Brevic.

Richmond, CA) RenderMan are frequently being used to create and animate as well as shade geometry. In *Lake Placid,* displacement shaders modify the geometry; in *Wild Wild West* and the *Fight Club,* shaders are used to create movement. All these techniques and more were used at Industrial Light & Magic (ILM) to create some 1700 digital shots for *Star Wars Episode I: The Phantom Menace.*

These movies demonstrate how skillful people have become at creating photorealistic computer graphics and in integrating 3D graphics with live action. A photorealistic penguin in the *Fight Club,* the bear, cow, and crocodile in *Lake Placid,* and a wasp in *Wild Wild West* illustrate this as well. But there's another kind of skill people are developing—that of creating non-photorealistic computer graphics. This was most artfully accomplished in *What Dreams May Come* to create the illusion of Robin Williams walking inside an oil painting, and more recently in the animated film *Tarzan* (See July 1999, pg. 50), in which 2D animated characters move through a jungle created with painted 3D backgrounds.

The short 3D animated film "Fishing," which will be shown in Siggraph's 1999 Electronic Theater, adds another medium—that of watercolor. This little film's simplicity stands in stark contrast to the richly varied texture of *Star Wars Episode I,* reminding us how multidimensional computer graphics can be.

The biggest gadget of all is a "tarantula," an 80-foot-high machine controlled by Dr. Loveless from an open cockpit in its "head." Made of wheels, cables, counterweights, and girders, the tarantula is like an eight-legged Eiffel Tower that walks, notes Simon Cheung, digital model supervisor, who created the huge model using Alias|Wavefront's (Toronto) Maya. Because each leg is different, he couldn't simply replicate one model eight times; however, to make the modeling task slightly easier, he was at least able to rely on displacement shaders for some of the rivets.

"We wanted to save as much modeling as we could, so we tried to do some things such as rivets and rust procedurally," says Craig Hammack, lead R&D technical director. "It was hard since some of the model is polygonal, so we ended up using Viewpaint." Viewpaint is ILM's 3D painting program, and with it, the painters created rust maps, scratch maps, dirt maps, oil maps, bump maps, and more, according to Steve Braggs, CG supervisor. "The big challenge was the need for detail," he says. "It's the largest hard-surface model we've built—six times the size of [*Jurassic Park's*]T. Rex. And in terms of paint, it has 20 times the number of texture maps."

When the tarantula walks, wheels turn, cables tense and relax, oil slides down the legs, giant pistons move at each joint, and steam is released from 46 little vents in the joints. With 150 moving parts in each leg, it's an intricate piece of machinery, and an interesting challenge for Dan Taylor, animation supervisor. "Barry [Sonnenfeld] wanted a sense of flawed mechanics; a machine that is strong, heavy, yet rickety," he says. "With a dinosaur, you can indicate muscle movement with bulges. Not with this." He studied how tarantulas move but discovered that they have no sense of weight, no footfall. So for the machine, he decided to

All Wild West images © 1999 Warner Bros./Courtesy of ILM.

At different times throughout the film, the evil Dr. Loveless rides in a CG wheelchair and walks on CG legs created at ILM.

Images © 20th Century Fox/Courtesy of Digital Domain.

For the opening scene in *Fight Club,* artists at Digital Domain traveled into a CG brain (right) and out of a hair follicle (above).

transfer movement from the leg to the body, and, after experimenting, keyed the weight off the leg closest to the camera.

Animation of various moving leg parts, on the other hand, was often handled procedurally. Expressions in Avid's (Montreal) Softimage 3D turned the wheels, dynamics in Maya moved cables, RenderMan shaders poured the oil and moved bump maps, a MEL (Maya) script caused steam to be emitted from vents automatically based on joint angles, and Maya particles created the smoke that pours out of the smokestack and, sometimes, mixes with real smoke. "It was complicated," says Alex Jager, visual-effects art director. "Real smoke has a surface tension between each particle, and simulating rolling and billowing smoke is hard." To create the effect, they used complex shadowing, highlighting, and textures inside the smoke.

In addition to the tarantula, ILM created several other CG effects, including Loveless's mechanical legs, which resemble those of the tarantula, a CG wheelchair to match the real one, a wasp that stings a tarantula during a campfire scene, and a mechanical "wasp," a rocket-powered unicycle with wings that's ridden—or rather, flown—by actors Smith and Kline. For this, after first creating the shot entirely using blue screen, the crew decided to switch to digital replicas in part. "The blue-screen actors look like little mannequins," says Taylor. "But with the CG wasp and riders, we could exaggerate the movement and sell the shot." For Will Smith, they used a cyberscan from *Men in Black;* Kevin Kline was modeled by Geoff Campbell, and photographs were mapped onto the models. All told, ILM worked on 400 shots for *Wild Wild West,* 100 of them 3D.

Fight Club

Director David Fincher's dramatic thriller *Fight Club,* for 20th Century Fox, starring Brad Pitt, Edward Norton, and Helena Bonham Carter, shows what happens when yuppie men have too much time and testosterone. The effects are used to help the audience understand what's going on inside the characters' minds.

For the opening sequence, Digital Domain was asked to trace a thought from its origin deep inside a human's brain until it emerges through a hair follicle on the sweaty scalp of Ed Norton's face. The task fell, appropriately, to Kevin Mack, visual-effects supervisor, who has, in his spare time, been trying to grow artificial neurology.

To create the enormously detailed 95-second shot, the effects team started with drawings provided by a medical illustrator that divided the shot, and thus the trip through the brain, into "rooms." In each "room," the artists attempted to be anatomically correct. Most of the geometry was created procedurally, using Side Effects Software's (Toronto) Houdini; rendering was accomplished with RenderMan.

© 20th Century Fox/Courtesy of Blue Sky Studios.

For a penguin that Blue Sky Studios was asked to develop for two shots in *Fight Club,* artists created an undercoat and an overcoat of feathers.

The first room is deep inside the amygdala, a structure in the forebrain and part of the limbic system that helps regulate emotion and memory. The shot opens with neurotransmitters (chemicals) being released by neurons (nerve cells that transmit information). To create the neurotransmitters, digital artist Dan Lemmon used Houdini's particle system. The result looks like a cloud of ink being released from a pore. From here, the camera pulls out into one of the most interesting "rooms" in the shot: a complex web of brownish-colored neurons, axons (long, fibrous neuron extensions that send information), and dendrites (shorter, tree-like neuron extensions that receive information). Streaking along the axons are neon-blue glowing lights, which represent action potentials, the electrical charge created when a neuron is activated and its internal membrane changes from negative to positive.

All this has been modeled, animated, and photorealistically rendered using research from scientific papers and images from scanning-electron microscopes for reference. To create the action potentials, digital artist David Prescott used Houdini to procedurally animate the object along a path generated by an axon, then rendered it separately. To create the axons and dendrites, Prescott used L-systems procedures implemented in Houdini. L-systems, invented by botanist Aristed Lindenmayer in 1968, offers rule-like descriptions of plant development—in other words, of a 3D form. By applying that description to itself, fractal and recursive forms can be created; by increasing the recursion level, the form can become more complex.

No animals were harmed to make this scene. The cow in the foreground and the crocodile emerging from the lake were both created with computer graphics by artists at Digital Domain for the film *Lake Placid*. Betty White is real.

To create the final objects, Prescott used metaballs, isosurfaces, and subdivision smoothing algorithms, then, because the resulting geometry was dense with polygons, he grew only nine sets (three resolutions) for each. The lower resolutions were used for objects not in close proximity to the camera. "We used real depth of field, not one faked with motion blur," he says. By using a clever system for creating nested instances, he could effectively multiply the number of sets that appeared in the final shot during rendering. To animate the axons and dendrites swaying in the brain's "gray matter," Lemmon wrote a displacement shader using RenderMan.

From this "room," the camera sends us through more brain matter, through a pore, into cortical bone, into the skin, through some fat cells, into a hair follicle, and out. At the end of the shot, we're looking at a microphotograph, in effect, of Ed Norton's face with beads of sweat on his forehead near the hairline. Texture maps painted by Martha Snow-Mack defined where hair would grow procedurally.

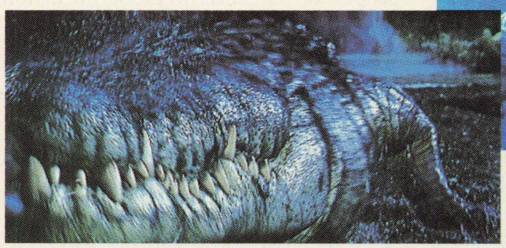
One of the most difficult things in the shot was trying to fly the camera through the complex web of geometry, but once a path was found, the digital artists would lock off the shot and start rendering. "The goal was to render once," says Lemmon. Render time averaged five to six hours per frame per element; each frame usually had three or four elements. "The difficulty is that because the brain is chaotic, every piece of geometry is in front of and behind other elements," says Prescott. But it looks amazing on the big screen.

Lake Placid

In this 20th Century Fox comedy/horror film, it's the crocodile that steals the show...and the cow, and the bear, and the helicopter, too. All of these were, at least for some of the shots, 3D objects created and animated by artists at Digital Domain. Directed by Steve Miner, the film stars Bill Pullman and Bridget Fonda, who battle a man-eating crocodile that lives in a remote lake in Maine, and Betty White, who seems to like the croc.

To create the effects, the digital artists, directed by visual-effects supervisor Andre' Bustanoby, used a wide range of commercial and proprietary software packages. Houdini particles created splashes in the lake as the croc surfaced; Paraform's (Palo Alto, CA) Paraform 1.0 software helped turn scanned data into a NURBS model that could be used in Maya and Softimage 3D; Maya's particles were used to move the sand under the crocodile's feet; Maya dynamics helped animators move the skin on the croc's belly; the fluid dynamics in Next Limit Research's (Madrid, Spain) RealWave software helped create the surface of the lake; and Nordisk Film's FurDesigner (Copenhagen) helped create the bear's hair. The helicopter model came from Viewpoint Digital (Orem, UT); the creatures from Zygote (Provo, UT). In many of the scenes, the crocodile is a Stan Winston "puppet." The bear is a combination of live action and CG in some shots, all CG in others. The cow that's eaten by the croc is a CG model.

Bustanoby took the need to match Stan Winston's crocodile seriously. "I wanted to make sure we didn't have to reinvent anything and that we leveraged as much of their artistry and sculptural technique as we could," he says. To take advantage of that artistry, the team scanned Winston's maquette to create the model, and rather than hand-painting textures, put the sculptural detail from the maquette into displacement maps. This not only made it easier to match the Winston model, but it also saved time. "I think that if we had hand-painted everything from scratch, it would have easily doubled the time to create the crocodile," he says.



All *Lake Placid* images © 20th Century Fox/Courtesy of Digital Domain.

To create the bubbles in the water above actress Bridget Fonda, the digital artists used Houdini's particle systems. The crocodile is a CG creature created to match a Stan Winston puppet.

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All *Inspector Gadget* images © Walt Disney Pictures/Courtesy of Dream Quest Images.

For *Inspector Gadget*, the effects team at Dream Quest Images integrated dozens of CG gadgets such as the flying bicycle handles (above) and the gadgetmobile (right) with live-action scenes.

The CG crocodile was used in scenes where it's moving fast—particularly when the animal is jumping out of the water to attack and when it's chasing people on land. The water scenes were particularly difficult because of the interaction between the CG model and the water. The waterline changes with the croc's movement, which meant the water needed to be CG (it was borrowed from *Titanic*); there were splashes to animate and reflections to accommodate.

But while Bustanoby would rather talk about the work his crew did to model, texture map, paint, animate, and render the digital characters and elements, such as the water, one of the most interesting aspects of his work with this movie was how he helped the director of photography (DP) previsualize the shots and then continued working with the team in production.

"We had an SGI O2 on the set running Softimage 3D," he says. In Softimage, he created a virtual set of the beach scene with digital camera rigs, low-res versions of trucks, people, and the crocodile, with several run cycles for the croc. By bringing this previsualization of the set to the location where the live action was being shot, he could show the DP what the scene would look like if he chose a particular lens and a particular camera, and the DP could make changes accordingly. "We wanted to be part of the production, not a hindrance," Bustanoby says. Once they were in production on the shot, the DP came to Digital Domain to help with the lighting. "It's like with previz on the set," he says. "We're trying to be part of the process."

Inspector Gadget

"This movie is about integration more than anything," says Richard Hoover, visual-effects supervisor at Dream Quest Images, which created some 350 shots for *Inspector Gadget.* Directed by David Kellogg, the Walt Disney Pictures comedy/fantasy film based on the animated television series *Inspector Gadget* stars Matthew Broderick as a disaster-prone special agent who is outfitted with a variety of gizmos, thanks to a doctor-cum-robotics expert.

Many of the CG gadgets created at Dream Quest were modeled after Stan Winston "puppets;" some were created solely with computer graphics; and most had to be folded up to fit into impossibly small spaces. A helicopter, for example, unfolds from Inspector Gadget's head. "They were always trying to show the audience a new gadget," says Hoover, "and the gadgets all had some kind of animation to fold up into small spaces, then telescope out. So the animation is elaborate, and fun to watch." What kind of gadgets? Pez dispensers, digital bubbles, mouth spray, a grappling iron, watches, a flamethrower, knives, a band saw, a toe rocket, a Bic pen than turns into a gun...and more. When Inspector Gadget wants to get someplace fast, he can drive away in his jet-powered gadgetmobile or he can run on 14-foot chrome legs, both created at Dream Quest.

The legs were particularly troublesome because the animators needed to match the actor filmed on a green-screen set while running in place on three-foot-tall stilts attached to bungee cords, according to John Murrah, 3D supervisor. They used tracking data to fit the motion precisely; to animate his pants, they used Maya Cloth. "The hard part was creating the wrinkles," says Rob Dressel, animation supervisor. "It's one thing if you're working with a robe, but pants wrinkle a lot, and getting those wrinkle patterns right is difficult."

How could this jet engine rise out of the impossibly small trunk? Only with the help of 3D models created at Dream Quest.

Also challenging was a shot where Gadget turns into an airbag—round body, fat legs and arms, little shoes sticking out at the bottom, head sitting on top. To animate the inflated Gadget, Dressel used lattices to bounce him around like a ball and zip him through the air when he gets shot. To put Broderick's face on the head, the team created macadam elements from the film taken of him during the green-screen shoot. (The ele-

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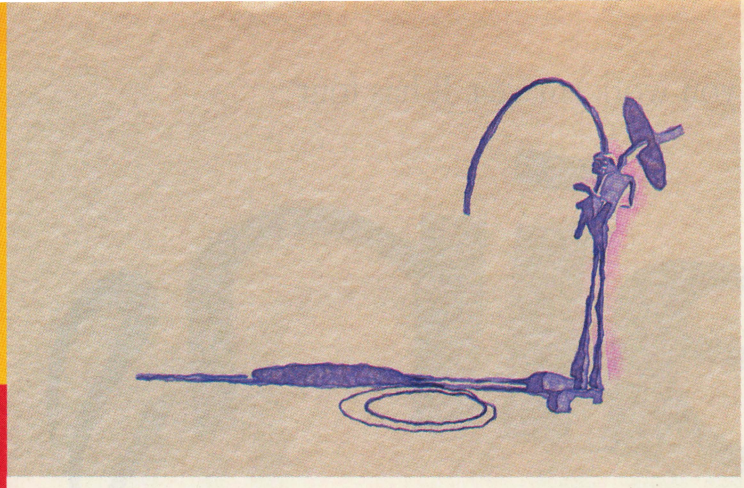


To create the hand-painted, watercolor look for this 3D animation, a small team at Pacific Data Images combined new technology with traditional artistic techniques.

ments look like maps created from a globe.) Then, they touched up the elements, wrapped them onto the 3D head, and let the movie run in 3-space as "inflate-o" Gadget bounces around. "It's sort of like the Haunted House at Disneyland," Dressel says. "When you're looking at him head on, he looks great, but if you saw him from the side, you'd start to lose it."

Fishing

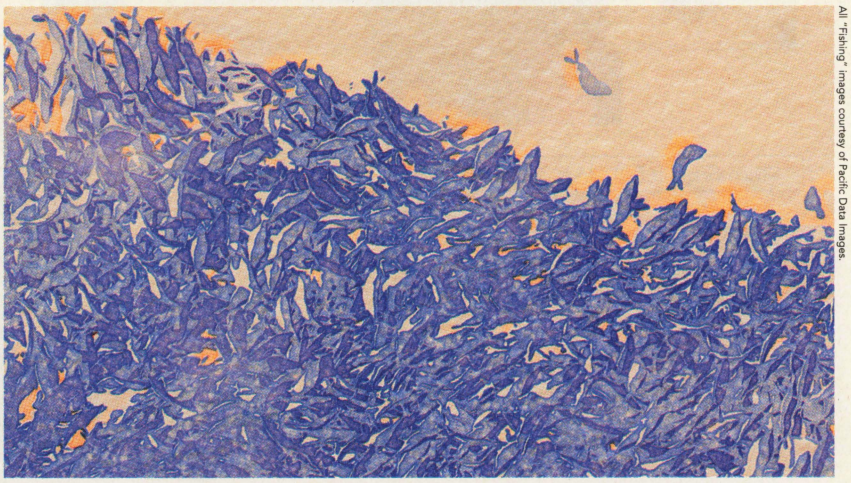
This short film, written, directed, and animated by David Gainey at Pacific Data Images, offers some interesting new ways to look at 3D animations. "Before [Disney/Pixar's] *Toy Story,* people didn't believe you could tell an interesting story with 3D computer graphics," says Cassidy Curtis, technical director, who created the watercolor rendering technique used for "Fishing." "I think we're in a similar place now with non-photorealistic rendering."

Fishing tells the story of a simple man who wants more and then gets too much. Gainey created the storyboards for the film with watercolors, and he could have painted each frame to create a cel animation that would have had the same look...almost. "Since most of our programs are 3D, there's a practical reason to use those tools," he says. "But aside from that, the environment we were trying to portray was a 3D environment. As I see it, the difference between the 3D environment in "Fishing" and the one in *Antz,* for example, is that we are choosing to reveal the fisherman's surroundings in the simplest, and most graphic way—a few brush strokes, if you will. I wanted to reveal shapes by painting in negative space. I was hoping to elicit the same emotional response from viewers that hand-drawn art elicits."

Helping Gainey realize the film were Scott Peterson, who created a method that allowed Gainey to hand-place ripples in the water and use parameters to control the animation, and Nick Foster, who modified his 3D fluid-dynamics program to work in 2D to create a Tsunami wave of fish. Curtis, who had worked with David Salesin at the University of Washington, provided the technology to implement the hand-drawn look. "I took what I learned in Seattle about what makes something look like a watercolor, and, rather than rein in the fluid-dynamics simulation, wrote an approximation in the scripting language at PDI," he says.

He starts with a black-and-white rendering of the 3D models that, because of the lighting, fades to complete white, and begins to create a negative space. "David would say, 'This line serves this purpose, this one is for shadow, this for background,' and I would set scripts to make that happen," Curtis explains. Then he used a combination of mattes and recursive algorithms to render an image that grew in the negative space. "These were all modulated with random noise to keep them lively, all done procedurally frame by frame," he says. The mattes were also warped with noise to make them grow and bleed; the colors used in the negative space changed with the time of day. In the last stage, Curtis lightened the interior and darkened the edges, using image processing and edge-detection techniques. For the paper, he simply used a synthetic paper texture and moved the paper with the camera.

In addition to the hand-painted watercolor look, Gainey took pains to make the film feel like a 2D work as well by restricting the motion and by rarely changing the size of the fisherman. "The action travels exclusively right to left, left to right, or up and down, with no travel or change of shape in the z axis," he says. In fact, there is only one shot in the film where the action travels toward the camera and the perspective is obvious—the opening shot when a fish jumps toward us through the water.



All "Fishing" images courtesy of Pacific Data Images.

Using the award-winning fluid dynamics program he developed for *Antz,* PDI's Nick Foster ran a 2D water simulation, then replaced particles with fish and pointed the fish along the paths of the particles' velocity.

Although Curtis hopes the techniques are used in other films, "Fishing" is the first and last film that will use the scripts he developed for it. "It's about the process," he says. "About what's needed to tell a particular story."

Barbara Robertson is the West Coast Senior Editor of Computer Graphics World.

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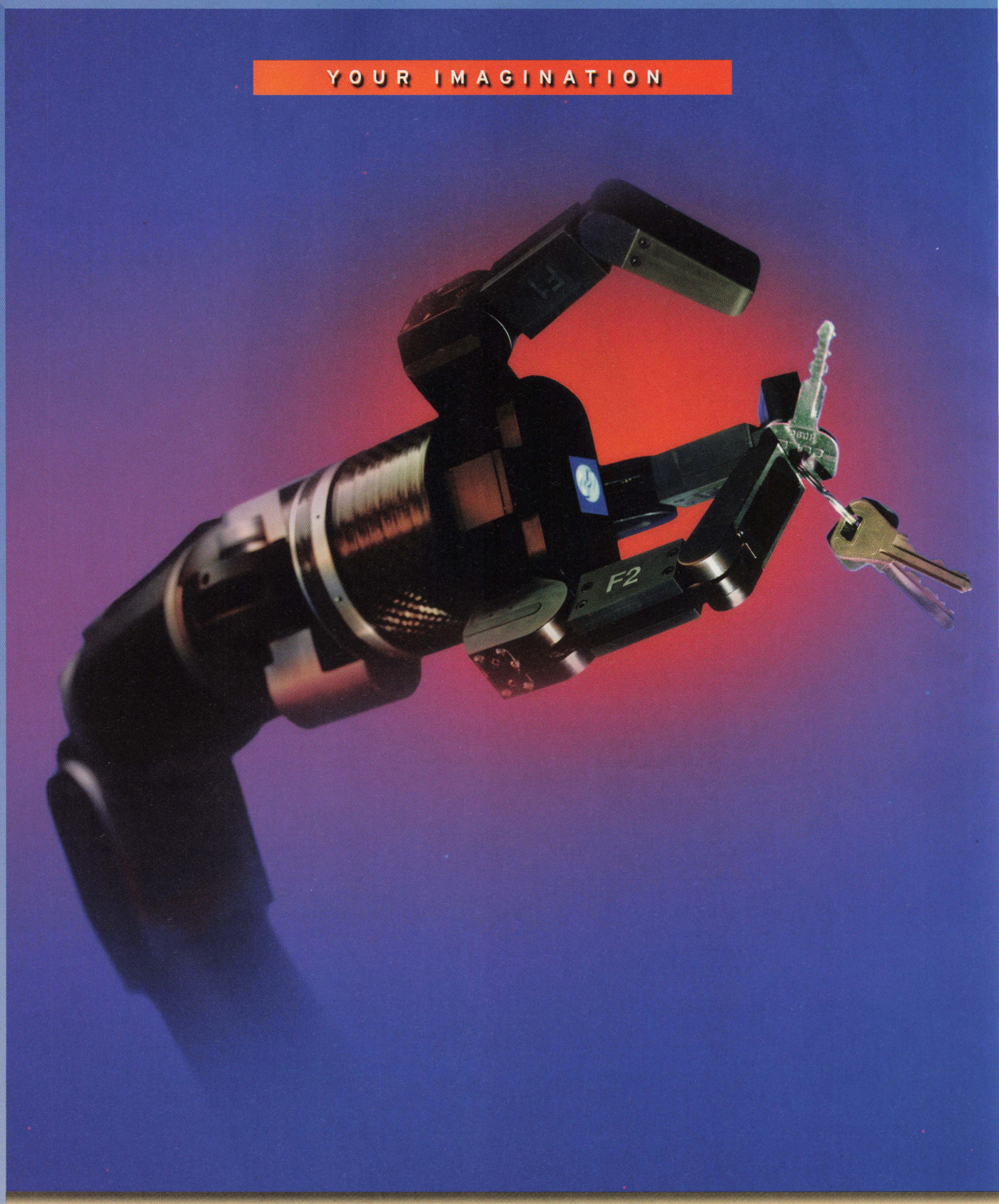

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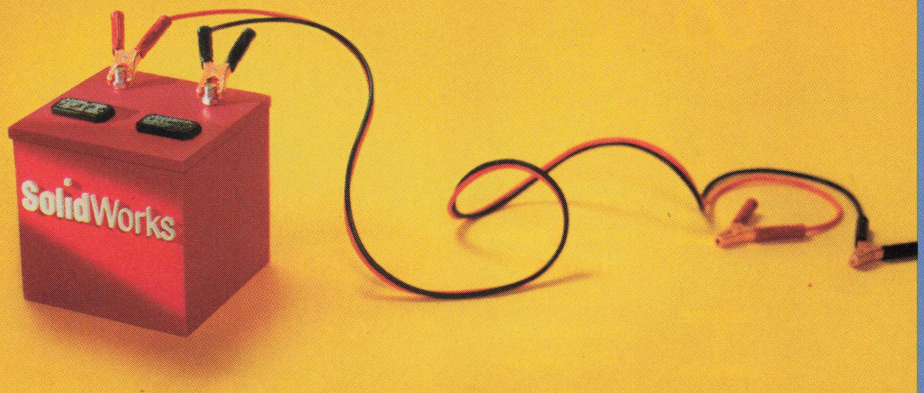

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STAR WARS BEHIND THE SCREENS

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To create the facial animation and lip synch for Boss Nass, animators used ILM's custom Caricature software.

ILM UNVEILS THE TOOLS IT INVENTED TO CRAFT THE COMPLEX GRAPHICS IN STAR WARS EPISODE I: THE PHANTOM MENACE

In November 1996, shortly after the script for *Star Wars Episode I: The Phantom Menace* was written, Christian Rouet, senior technology officer at Industrial Light & Magic, got his first look at the concept art for what would become the most complex mixture of computer graphics with live action the studio had ever faced. "I could see that we would have big throughput issues," he says. "We had to make the workflow more efficient." Two months later, 15 software engineers working under Rouet in ILM's R&D department began revamping the studio's existing tools and creating new ones to make it easier and faster for modelers, painters, animators, CG supervisors, and technical directors to practice their craft. Processes that were cumbersome became interactive, animation that might have been tedious became automated, and familiar tools got facelifts.

With ILM's Caricature software, animators have shape-blending tools for manipulating elements in complex 3D models. Developed originally for facial animation and lip synching, Caricature is now used for secondary animation as well. Recently, the tools Isculpt, for resculpting models, and Carienv, for enveloping (moving skin over muscles), have been folded into the system.

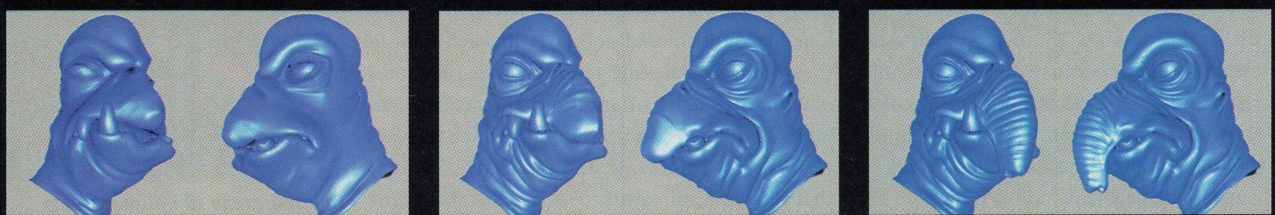
Other than the small "rebel Mac unit" at ILM, the computer graphics pipeline is based on SGI hardware and commercial software such as Pixar's RenderMan, Avid's Softimage 3D, and Alias|Wavefront's PowerAnimator and Maya that are all integrated with ILM's custom software. It's rare for ILM to reveal much about its proprietary tools, but this year the R&D department created a short film describing its work, which will be shown at the Electronic Theater during the Siggraph conference this month. Among the upgraded tools highlighted in the film are those for facial animation and lip synch, modeling, enveloping, socking, tracking, painting, and compositing. New tools showcased in the short film include a dynamic simulator, a choreographer, a 3D match-move program, and an adaptive terrain generator, among others.

Shaping

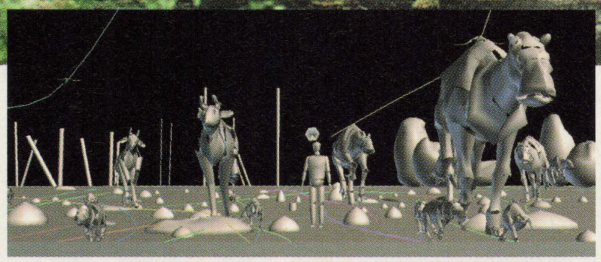
With 66 different character types to be modeled and crowds to be animated, much of the R&D department's focus was on making life easier for character teams. Most characters were modeled with commercial 3D software, then refined with ILM's Isculpt software. With Isculpt, modelers can make symmetrical changes to a model even if the topology, geometry types, and resolution are different in each half of the model. To deform geometry within Isculpt, a modeler would typically use a 3D brush of arbitrary size centered on any point in 3-space, not necessarily a vertex. "[The brush] basically captures a bunch of geometry within a certain distance," says James Hourihan.

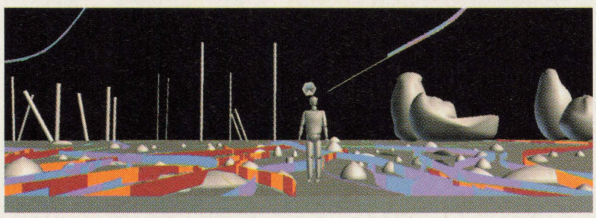
Thus, a modeler can pull, push, twist, and move geometry around smooth surfaces; create wrinkles; and paint weights that are respected by symmetric operations. "If you painted a seam on clothing, it could create the opposite weights on the other side and if you were to grab the seam, it would grab the weights all together so that you could interactively stretch, yank, and smooth the grabbed portion," says Hourihan. One big advantage of Isculpt: It gives modelers a way to reshape a model to, for example, create an entire race of Gungans.

"The overwhelming challenge was in upgrading and enhancing our tools to sustain the volume of work," says Cary Phillips. "We had to make things faster because people would have less time to set up and animate creatures than on other shows." Phillips was largely responsible for creating the system known as "Caricature," first used by



To create Watto's snout, modelers reshaped the basic geometry using Isculpt.





With "Fred," shown here, animators explicitly choreographed all the CG animals in the stampede scene.

animators to create facial animation and lip synch for the dragon in *Dragonheart.* Although Caricature's underlying technology didn't change, Phillips overhauled the interface knowing that in *Star Wars,* CG characters would talk to each other. "The best thing about Caricature is the instant feedback," says Tim Harrington, an animator who helped perform Watto and Boss Nass. "We can dial in a face shape, move muscles, make fat jiggle, and see results immediately."

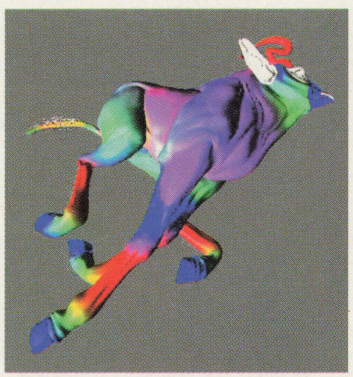
Once a basic shape for a character has been created, the character must be skinned and "enveloped." The skin itself is like a patchwork quilt made of spline surfaces—four-sided patches that are stitched, or "socked," together. The R&D team optimized ILM's socking software, which dated back to *Terminator 2,* and upgraded it to handle complex 3D characters that often have small areas, such as the corners of a mouth, where several patches must be stitched together. "It's the last step of the geometry pipeline for a creature before it goes to animation," says Nicolas Popravka, who worked on the new software, "so it's very sensitive." If patches are not tightly connected, cracks show up in the final rendering. "Cracks are the nastiest of problems because they often manifest themselves as tiny amounts of color showing through from a surface behind, and it's not always obvious that a crack is causing the problem," adds Phillips.

To move the skin over the surface so that it looks as if there are muscles beneath, ILM uses a technique called "enveloping." Put simply, enveloping relates the skin to joints in the skeleton so that when the skeleton moves, it pulls the skin along with it. Vishwa Ranjan rewrote the original system, first developed for *Jurassic Park,* to shorten the learning curve and make the process interactive. Equally important, the new system created a spatial relationship of skin to joints that is now independent from the surfaces being enveloped. This meant that envelopes could be re-used, and the underlying model could change after it was enveloped. "We realized that during the evolution of a creature, the model changes more often than people might think," Ranjan says.

Choreography

To move characters, animators typically created key poses in Softimage, but for individual scenes such as the stampede of CG animals on Naboo early in *Episode I,* they needed to maneuver 61 scared critters. The R&D group responded by creating "Fred." With Fred, animators first created a library of motion cycles and transitions between the cycles for each animal. Then they imported geometry for the 3D scene—a simple terrain and some props—into Fred along with the characters and their traditionally animated walk cycles. Fred separated the geometry and animation for each character and reduced the resolution of the geometry to achieve a variety of 3D representations that ranged from small, sprite-like stick figures to larger, fleshed-out creatures.

"We split the animation and geometry to keep as much as possible in memory, which makes it run really fast," explains Zoran Kacic-Alesic. Once all the pieces are available, animators draw paths on the terrain, assign characters to the paths, and apply motion cycles to the characters. The paths look like multicolored ribbons, with each color in the ribbon representing a motion cycle. To choreograph the paths of multiple characters, Fred offers both a 2D edit decision list, which displays each clip on a time line, and interactive 3D tools that allow the animators to slide elements in time or in space. "It's like a film-editing system except



Colored areas of influence help envelopers define skin movement.

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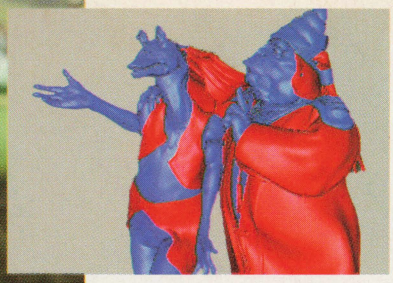


Using custom cloth-simulation software and a texture map relaxation technique, ILM's R&D department helped these characters become believable.

it also has a 3D component," says John Horn. For example, an animator can pick up the ribbon and move it in while a creature is running, and can change the length of any motion cycle by stretching or shrinking the colors on the ribbon.

Simulation

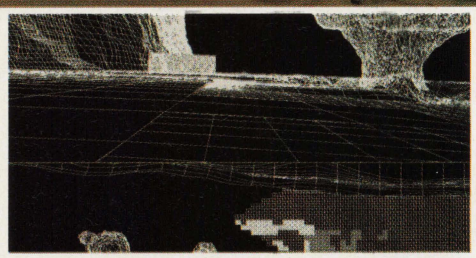
Fred gives animators explicit control over a crowd of hundreds of individual characters. To animate more characters, the effects crew used particle animation in Maya. But to add animation to individual keyframed characters, the R&D department created procedural animation and simulation tools. For example, because existing tools for doing rigid dynamics couldn't deal with stiffly constrained systems like the droids, according to Hourihan, ILM created its own rigid-body system that can live in a hierarchy. "It's in a gray area between being a kinematic chain and a rigid-body solver," he explains.

More widely used were the simulation tools created by John Anderson, who explains that once his team got started, they ran hundreds of simulations on materials ranging from soft to stiff. "Most of the characters have procedural animation on them," says Anderson, "because it allows you to get some complexity in the motion that's not very expensive. The simulator uses a physically inspired model, as Anderson puts it, with a representation of what they determined were the important properties of the object or material being animated. "It's basic stuff," he says, "but what makes it different is the degree to which we can control procedural animation to make it fit with keyframed animation. Another advantage is that the system works with one, two, or three dimensions. "[Simulation] is easier to control if you don't have undesirable degrees of freedom," Anderson says. "There's no sense in using a 3D representation of something if it's fundamentally a 2D thing." In fact, although the 3D simulator was used in *The Mummy* (see May 1999, pg. 34), the procedural animation in *Star Wars* was primarily 1D and 2D. The string-like objects, such as the skin dangling from Sebulba's chin and the antennae on the sea monsters, were animated with a 1D simulation, while the membrane the submarine goes through, Jar Jar's ears and the clothes the characters wore were animated with a 2D simulation.

The cloth simulation created a problem, though—it stretched and distorted the textures. "The cloth was made of non-stretching material, so the texture on the cloth needed to remain uniform," says Ranjan. To solve this problem, he and John Anderson developed a "relaxation" scheme that tried to maintain the appropriate distances for the texture on the model during the simulation.

To offer the pod-race unit an interactive tool that could emulate final renders, ILM created terrain generation and rendering software.

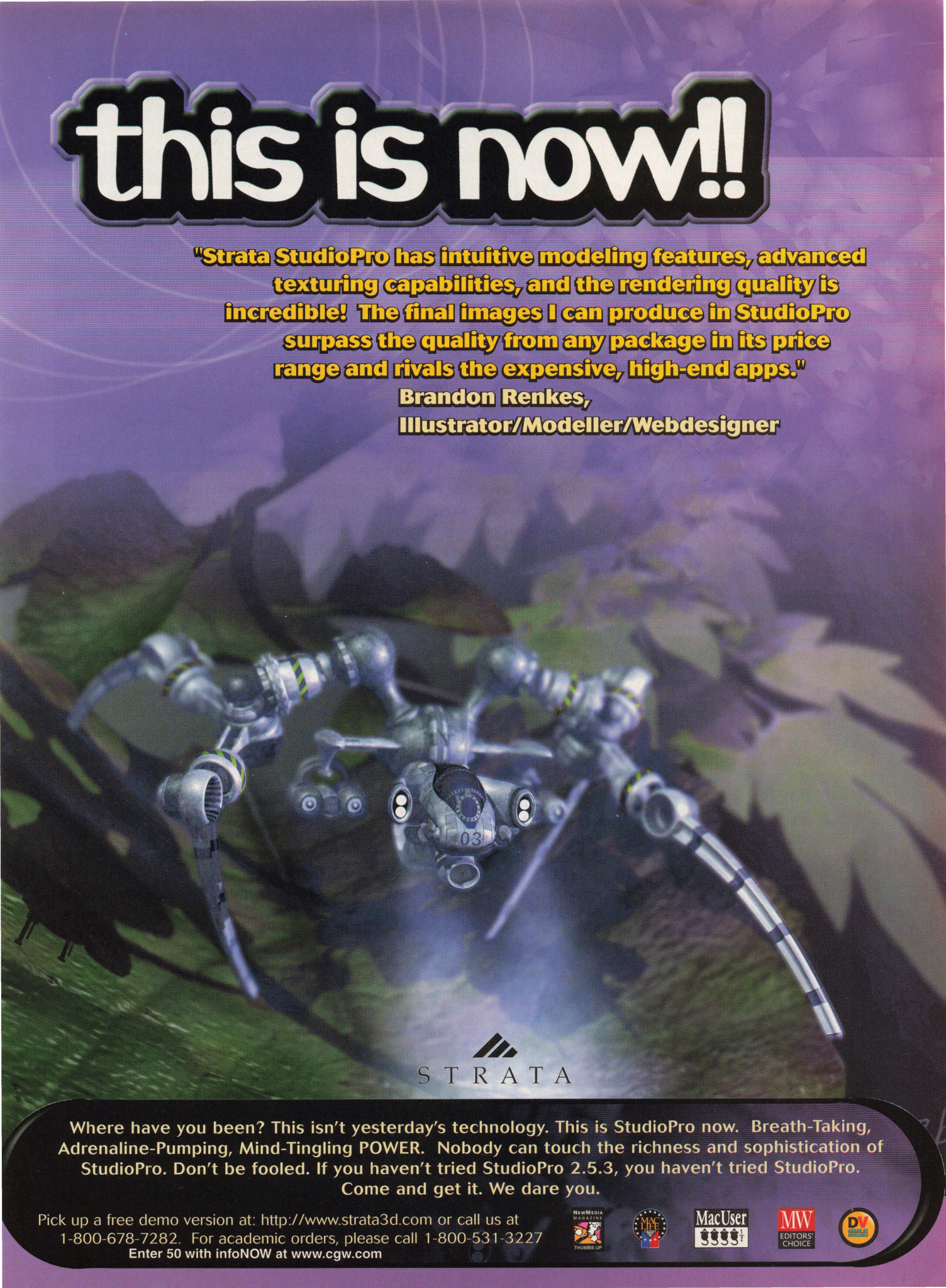
In addition to solving the stretching problem, the software optimized the texture coordinates so that fewer pixels could be used, and clothing could have seams.



Generating Terrain

One of the most dramatic sequences in *Episode I* is the all-CG pod race. To give the pod-race team a way to work interactively with a terrain that zips along at 600 miles per hour, and to generate the terrain for the final shots, the R&D team created a three-part adaptive terrain generator. In stage one, a specification was created using data that determined how much detail was in a particular region and how high the resolution needed to be. The actual terrain could then be generated using information from a pre-pass, according to Alan Trombley.

In the pre-pass stage (stage two), terrain geometry was created at all possible resolutions, and each resulting shape, or tile, was compared to the highest-resolution tile. Thus,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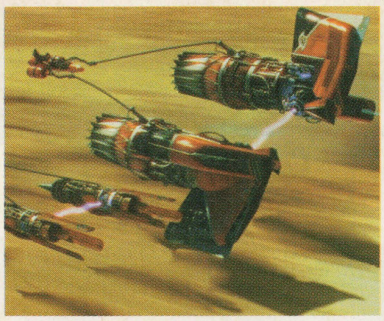
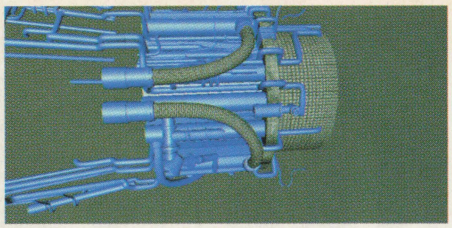
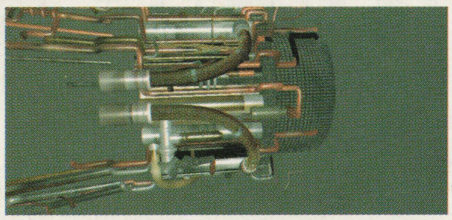
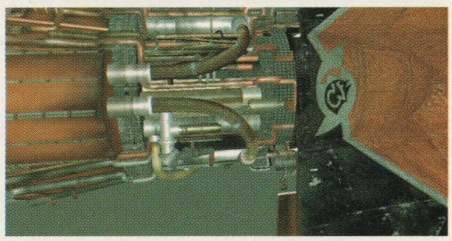
what was stored in memory was information for the detail in each tile, for each resolution of each tile, and for the difference between any tile and the tile with the highest resolution. "The key is that this data is small, so we can hold many frames in memory," Trombley explains.

In stage three, the software determined whether a tile was in view. If so, it decided which version of that tile to create based on its distance from the camera. This is similar in concept to dynamic paging used in flight simulations, according to Rouet, with one distinction: "It's much more precise." Trombley agrees: "Most flight simulators don't care whether the terrain flickers a little as you approach it. But that would be a disaster for us." Thus, once the system decides which resolution is acceptable, it creates that tile and the one next in line with more detail and higher resolution, then interpolates the geometry so that the actual tile displayed is a blending of the two. "At the moment when the system is going to switch to another tile, it's actually already made the previous tile look exactly like it," Trombley says.









Painting this complex engine from Sebulba's pod became a little easier with the navigational tools and texture-mapping options added to ILM's custom Viewpaint software.

Painting

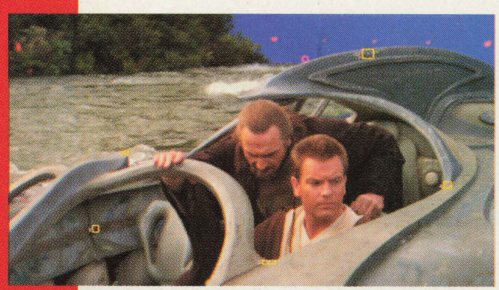
Even though it would be impossible to work interactively with a final rendering of the terrain, ILM comes close with "Irender." Incorporated into Viewpaint, ILM's 3D paint system, Irender provides an interactive lighting environment and simulates a RenderMan rendering. "Previously, painters had to wait for TDs to render a scene so they could see what the paint looked like," says David Benson. Now they can see a fast approximation that takes into account opacity, bump, and displacement maps. For the pod race, Irender generated an interactive simulation of the terrain with shadows.

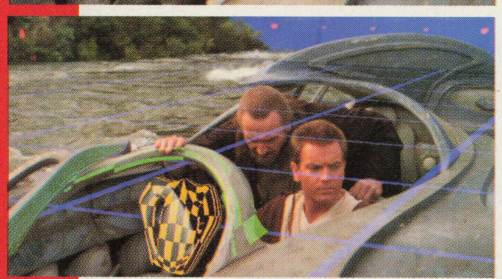
Viewpaint itself was revamped for *Star Wars,* for complex hard surfaces such as those in the pods. "If you think that each of the thousands of pieces of Sebulba's pod has a shader with textures, all of which have to be painted, you can see that navigating through such a complex model hierarchy to pick the part to paint is by itself difficult," says Rouet. "Plus there is a diversity of primitives: polygons, trimmed nurbs, patches." Moreover, the team had to face issues such as texture stretching that were unique to the hard surfaces. Ultimately, by combining Irender with Viewpaint, the painters were able to choose cylindrical mapping, projection mapping, or to explicitly assign textures to surfaces and see, interactively, a simulation of the final result, according to Eric Shafer.

Two other proprietary systems were used extensively for *Star Wars:* a 3D tracking system that helped animators precisely place characters in live-action scenes, and CompTime, a new compositing system.

Although some shots were composited with Sabre, ILM's extensions to Discreet Logic's Flame and Inferno software, CompTime was the compositing tool for the CG department, according to Jeff Yost. First used for one shot in *Saving Private Ryan,* CompTime is based on the studio's long-time scripted system, but now boasts a graphical user interface and hooks for plug-ins that can be written in Python or C++. Tim Alexander, a compositor for *Star Wars,* took advantage of the plug-ins, for example, to write filters that emulated particular camera lenses. In addition, CompTime allowed many people work on one shot; the system merged the work together into a final script.

Although many of these tools were created for *Star Wars,* they've already had an impact on ILM's work on other movies. "We were able to get such a high throughput without lowering our quality," says Kevin Rafferty, CG supervisor. "It will definitely affect the way we bid shows."





In addition to capturing the live-action camera move with Loupe, ILM's tracking software, software engineers added a 3D model-match feature that automatically gave animators object-based movement to better help them fit CG characters inside moving objects.

Barbara Robertson is West Coast senior editor for Computer Graphics World.

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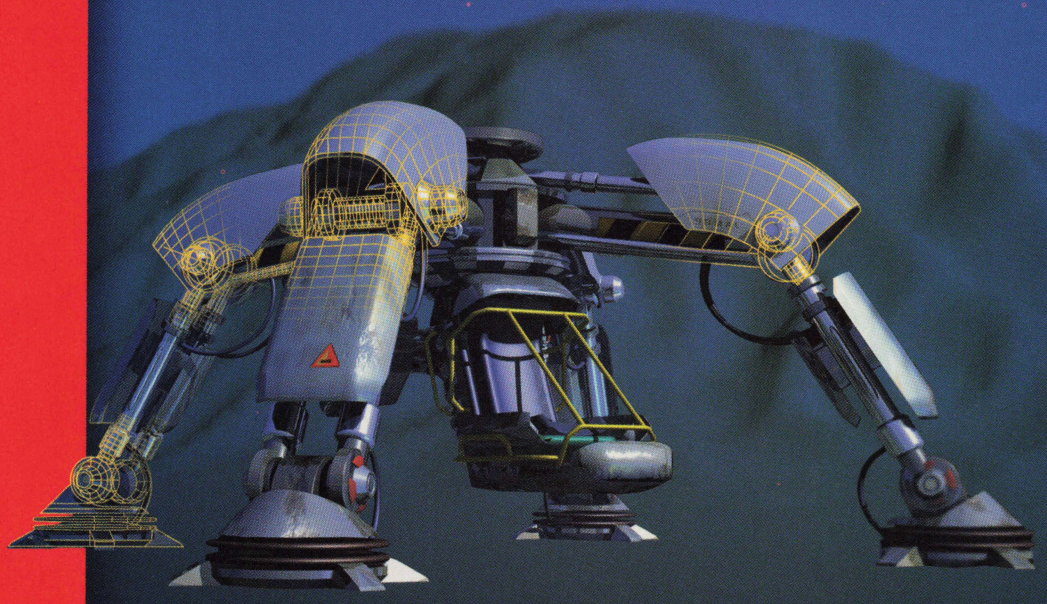

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Finally there's a mid-range price for ultimate NT graphics performance, thanks to the innovators at Diamond Multimedia and IBM. The Fire GL1 offers graphics professionals using NT workstations 2D and 3D graphics acceleration, which not only outguns the competition for performance, but also for price.

How does Fire GL1 outperform competitive products?
By delivering 4 million polygons per second, a ProCDRS rate of 20+ and 351 HE 99 WinMarks, the Fire GL1 offers the best performance in its range. How does it do this? With the first 256-bit graphics engine, multi-threaded OpenGL drivers and by supporting Intel's Pentium III and Xeon's Streaming SIMD Extensions.

The result...
With its unbeatable 2D and 3D power, performance and price, the Fire GL1 is ideal for any professional in the digital content creation market, from 3D animators and CAD engineers to web content creators.

Diamond Fire GL1 – Ultimate Technology, Ultimate Graphics

For more information and details of where to buy the Fire GL1, call Diamond Multimedia on **1-800-468-5846** or visit:

firegl.diamondmm.com

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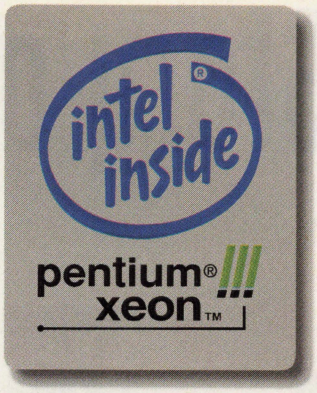
Robot image created by Blur Studio, Inc.



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The Story of Computer

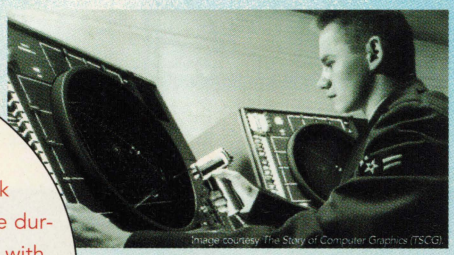


Image courtesy The Story of Computer Graphics (TSCG).

The SAGE Machine, aka Semi-Automatic Ground Environment, is created to track enemy aircraft entering US air space during the Cold War. Computers built with 50,000 vacuum tubes apiece are integrated with radar systems to provide the first interactive computer graphics: Using a special light pen, operators can zero in on suspicious blips on the screen.

William Fetter creates takeoff and landing studies with wireframe aircraft at Boeing. He also creates the so-called "First Man," a digital human placed in a digital cockpit so that design engineers can see if his hands reach the controls.

At Bell Laboratories, Ed Zajak's "Satellite Movie" demonstrates how the results of a scientific calculation can be displayed as a moving picture.

The University of Utah recruits Dave Evans to found the first computer graphics department.

1955 **1963** **1966** **1967**

Ivan Sutherland demonstrates the Sketchpad interactive graphics software he has developed at M.I.T. "I was driven by the idea that I could integrate a numerical representation of an object with a graphical representation and that by manipulating the graphical representation I could manipulate the underlying numerical representation."

DAC-1, a proto-CAD system based on technology from IBM, goes into use at General Motors. Its designers are motivated by the idea of controlling a milling machine with a computer.

GE introduces a full-color flight simulator. The airplanes look blocky, and require a lot of hardware in order to run.

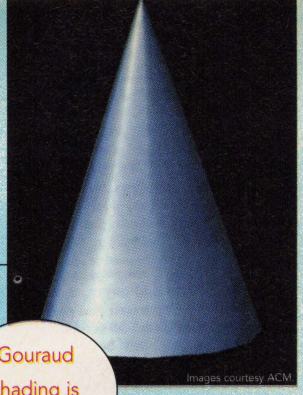
From its early development as an obscure research topic to its current role as a vital communication tool, computer graphics has a rich history of innovation. The time line that follows highlights technological milestones from the full-length documentary, *The Story of Computer Graphics*, which premieres at Siggraph this month.

Image courtesy The Bootstrap Institute.

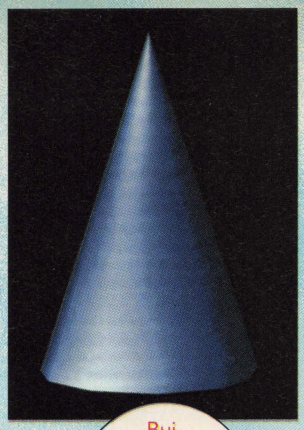
Douglas Englebart invents the mouse.

Image courtesy SRI International.

Graphics



Gouraud shading is introduced.



Bui-Toung Phong creates Phong shading at the University of Utah.

Steve Wozniak and Steve Jobs build the first Apple computers in a garage. Bill Gates founds Microsoft with Paul Allen.

Dave Evans and Ivan Sutherland found Evans & Sutherland.

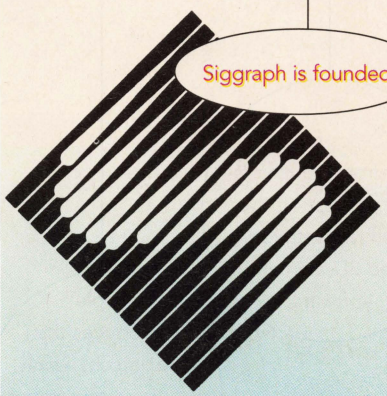
Ivan Sutherland builds the first heads-up display at the University of Utah.

Video game Pong developed for Atari.

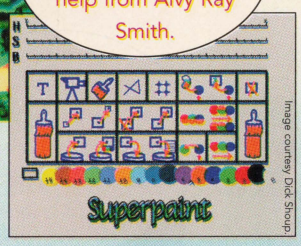
Ed Catmull develops the z-buffer at the University of Utah.

Jim Blinn develops image and texture mapping.

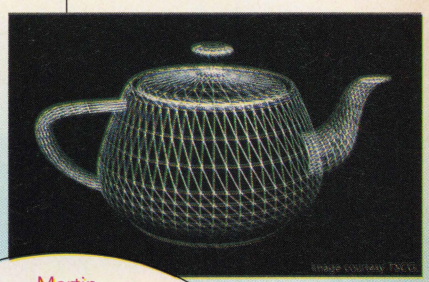
1968 1969 1970 1971 1972 1974 1975 1976



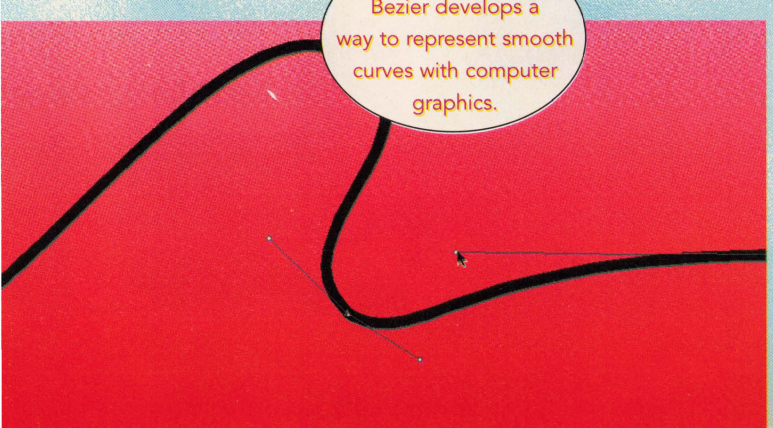
Siggraph is founded.



Dick Shoup invents SuperPaint, with some help from Alvy Ray Smith.



Martin Newell at the University of Utah develops a CG version of a teapot, which becomes the computer graphics icon. Over the years, researchers use it to demonstrate new technology. Says Jim Blinn, "You had to measure it and enter the numbers into a computer, then draw lines between your numbers. You got rid of the lines on the back, filled in the facets, and simulated the physics of shining a light on it and viewing how the surface is shaded."



Pierre Bezier develops a way to represent smooth curves with computer graphics.

Quantel creates Paintbox, the first commercial graphics product designed specifically for broadcast. An artist working in television can work directly on the screen instead of shooting pre-created graphics with a camera.

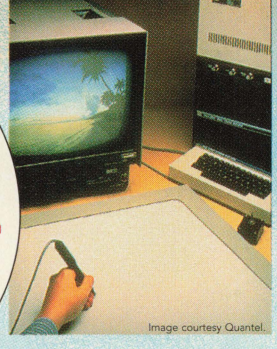


Image courtesy Quantel.

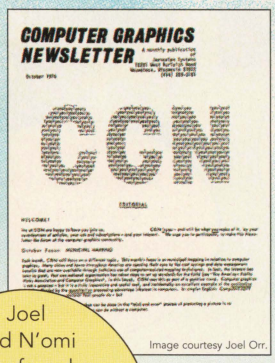


Image courtesy Joel Orr.

Joel and N'omi Orr found *Computer Graphics Newsletter* in 1976. Under new ownership in 1977, it becomes *Computer Graphics World*.

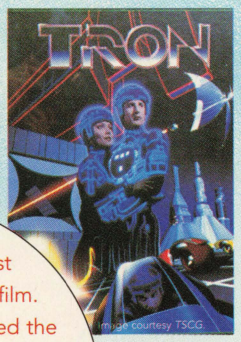


Image courtesy TSCG.

Computer graphics plays its first major role in a feature film. Disney's *TRON* "consumed the better portion of the computer animation production industry for the better part of a year," says Richard Taylor. "And it bombed." Nonetheless, *TRON* inspires others to more successful efforts.

Image courtesy SGI.

Silicon Graphics ships the Iris 1000, the first workstation with a geometry accelerator on a chip.

Founder Jim Clark:
"We custom built chips that put into silicon the most computationally complex and repetitive calculations used in computer graphics."

1977 **1978** **1979** **1980** **1981** **1982** **1983** **1984**

IBM introduces the PC.

Autodesk introduces the first PC-based CAD software.

Bill Kovacs founds Wavefront, which creates the first off-the-shelf, workstation-based 3D-animation software.

Apple introduces the Macintosh, which will go on to computerize the graphic arts industries.

Artist Leroy Neiman uses Alvy Ray Smith's Ampex paint system to draw football players at the Super Bowl.

Turner Whitted introduces ray tracing.

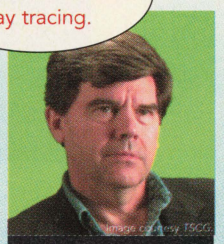
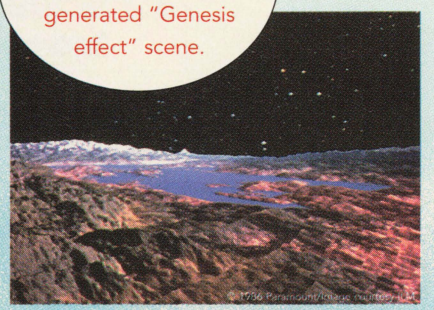


Image courtesy TSCG.

"It took 24 hours to calculate each frame of my ray-traced spheres, or, by extrapolation, four years to calculate just one minute. So we had found a tool but did not have the power in our grasp to use it."

Star Trek II: The Wrath of Kahn includes the groundbreaking computer-generated "Genesis effect" scene.


© 1986 Paramount/Lucasfilm courtesy LEC

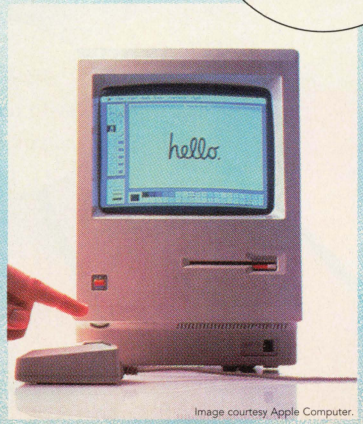


Image courtesy Apple Computer.

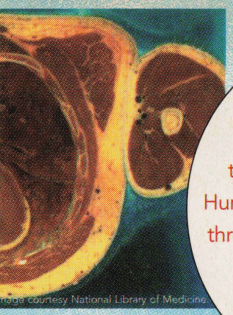


Image courtesy National Library of Medicine.

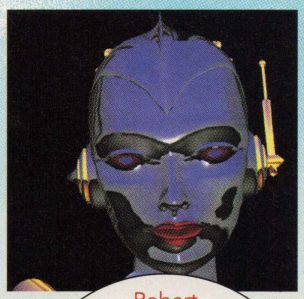
The National Library of Medicine makes plans to undertake the Visible Human Project to reconstruct three-dimensional data from CAT and MRI scans of male and female cadavers.

Image courtesy ILM.

Industrial Light & Magic creates a water creature that briefly mimics a human face for the movie *The Abyss*.

Image courtesy Paramount, 20th Century Fox, Digital Domain.

Digital Domain receives an Academy Award for its special effects work on *Titanic*.



Robert Abel's Sexy Robot appears in a television commercial, setting new standards for CG body motion.

Matt Elson's Lotta Desire, the leopard-skinned CG star of the short film "The Little Death," demonstrates displacement animation.

Image courtesy of NCSA and the Department of Atmospheric Sciences, UIUC.

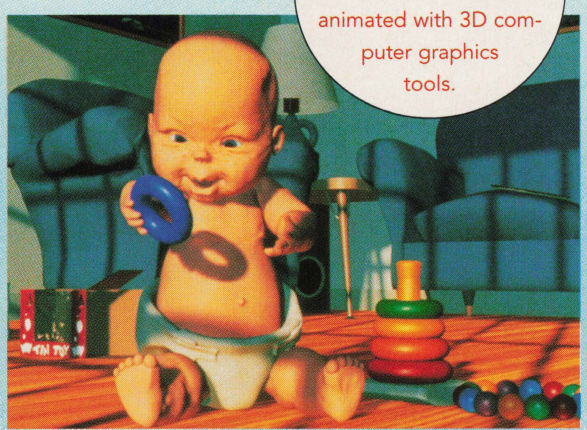
Researchers Bruce Lee and Robert Wilhelmson create simulations of tornadoes in order to better understand their behavior.

Siggraph celebrates its 25th annual conference.

1985 **1986** **1989** **1992** **1994** **1995** **1998** **1999**

The Targa card, a 16-bit video frame grabber and frame buffer for PCs, is introduced by AT&T.

Pixar wins an Academy Award for the short film "Tin Toy," the first movie animated with 3D computer graphics tools.



The CAVE virtual reality theater, developed at the University of Illinois, premieres at Siggraph.

Industrial Light & Magic wins an Oscar for special effects in the film *Jurassic Park*.

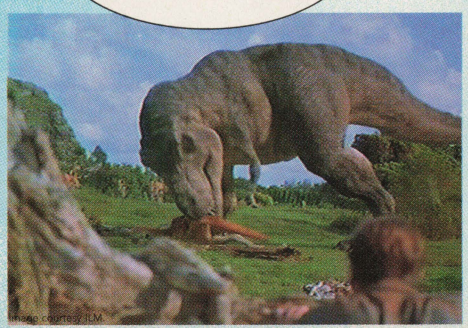
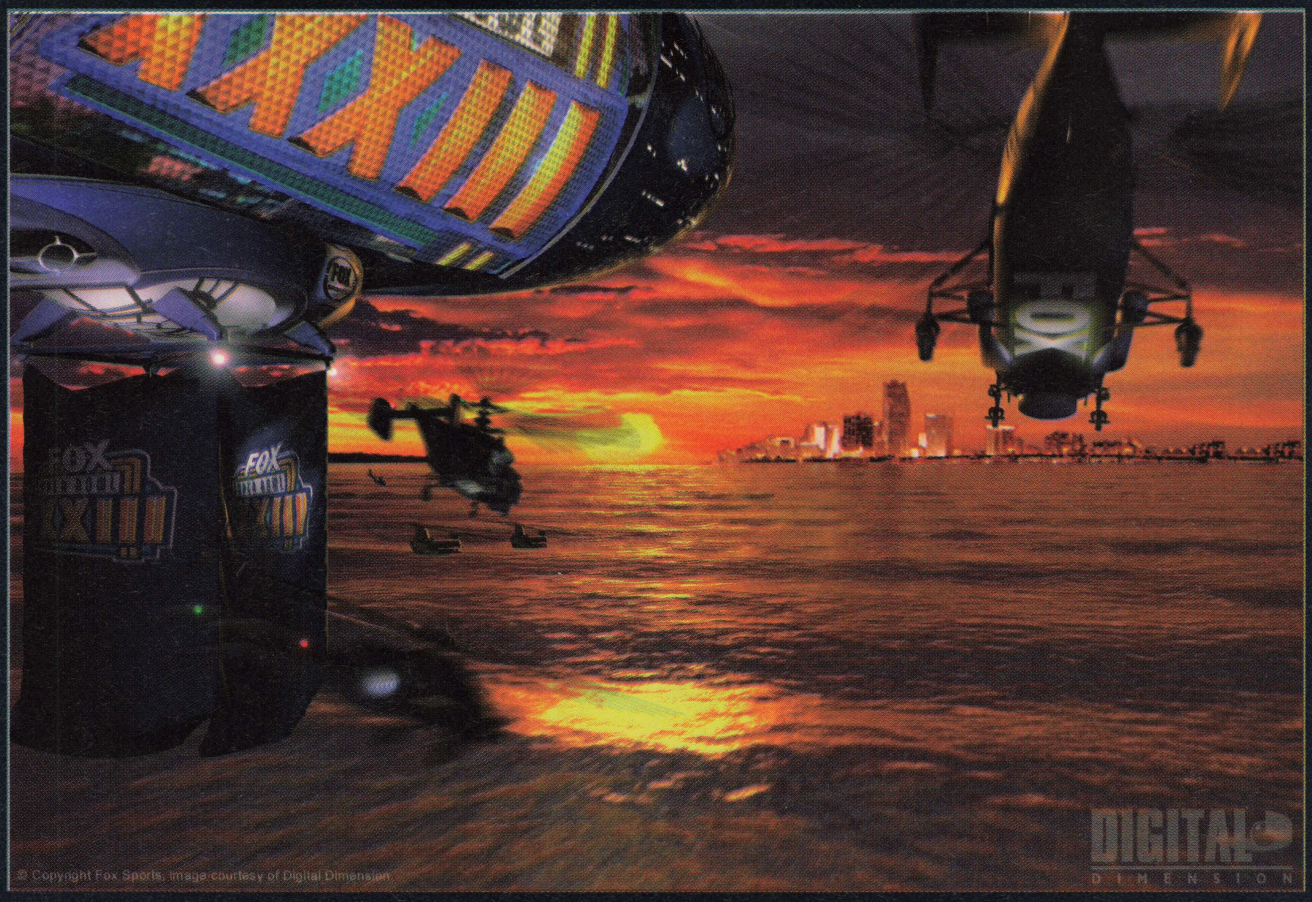


Image courtesy ILM.

Pixar's John Lasseter receives a special achievement Academy Award for *Toy Story*, the first 3D computer-animated full-length feature film.

Star Wars Episode One: The Phantom Menace contains more than 66 digital characters. One, Jar Jar Binks, plays a leading role in the film.

Lucasfilm, Ltd & TM. Image courtesy ILM.



© Copyright Fox Sports. Image courtesy of Digital Dimension

"We needed to find a way of dealing with the huge computing loads that serious ray tracing presents..."

The Super Bowl is the single biggest event in broadcast television, with up to 800 million viewers worldwide. This year, Fox Sports was looking for someone to produce a visually stunning animated opening sequence for "*Super Bowl XXXIII on Fox*". They turned once again to Digital Dimension, a North Hollywood-based studio specializing in 3D animations, motion graphics, and visual fx.

Digital Dimension faced a number of challenges. First of all, the project needed to be completed rapidly. With a short time to complete the job, and lots of creative interaction with Fox expected, speed was of the essence. Secondly, while much of the sequence could be done using conventional tools and methods, the inclusion of large stretches of water and a gigantic replica of the Vince Lombardi Trophy meant that they would have to be ray traced in order to achieve the level of photorealism required.

Normally, installing the rendering resources on the scale required by a project of this complexity would have been a difficult, expensive, and time consuming process. But thanks to RenderDrive's revolutionary rendering technology, it proved quick and trouble free.

Fox Sports loved the finished results, and Digital Dimension's animators loved the quality and power of the RenderDrive. In fact, they may need to break out their dress shoes again for this year's Emmy awards ceremony.

"We could not have done this project in the time allotted and to the quality standard that Fox requires without the power, speed and increased interactivity that RenderDrive gave us."

Ben Girard
General Manager, Digital Dimension

Ray tracing finally makes sense

RenderDrive

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PROCESS CONTROL

POISED FOR TAKE OFF, CAD/CAM'S NEWEST TOOL—PRODUCT PROCESS MANAGEMENT SOFTWARE—AIMS TO CONTROL BOTH THE DATA AND THE METHODS USED TO DESIGN COMPLEX ASSEMBLIES

BY CAREN D. POTTER

To manage volumes of data generated by far-flung design teams working on the C-17 Globemaster aircraft, Boeing uses iMAN, Unigraphics Solutions' PPM software.

Have you ever felt so overwhelmed that if someone offered you one more new technique to help you work more efficiently, you'd tell them to get lost? This is how some manufacturers are reacting to the latest technology to hit the CAD/CAM industry, something called Product Process Management (PPM). Indeed, the response to PPM at a recent Daratech conference on the subject was somewhat less than enthusiastic. While no one actually told PPM proponents to get lost, several users openly expressed frustration that vendors wanted them to buy something more complex when they weren't even able to get their existing CAD/CAM and product data management (PDM) implementations to work together.

What exactly is PPM? According to Daratech vice president Bruce Jenkins, "PPM is a collection of user strategies, IT technologies, and infrastructure that makes it possible to manage the workflows, methodologies, and procedures that companies use to create new products."

Stacey Lawson, vice president of product marketing and strategy at Parametric Technology Corp. (PTC), a developer of PPM systems, gives a slightly less formal definition: "PPM brings many fragmented applications such as CAD, PDM, CSM (component supplier management), product planning, and process planning into a cohesive, integrated suite of applications that addresses the full product life cycle, from birth to retirement."

If you're still confused, there's a good reason. Explaining PPM is difficult because no vendor actually uses the term to describe its technology. PPM serves more as an umbrella phrase under which a number of new initiatives fit. In fact, companies such as PTC, Unigraphics Solutions, IBM's Enovia Corp., and SDRC's Metaphase all convey a similar theme—a move beyond traditional PDM to something broader and presumably better, because it encompasses the process of product design rather than just the management of product design data.

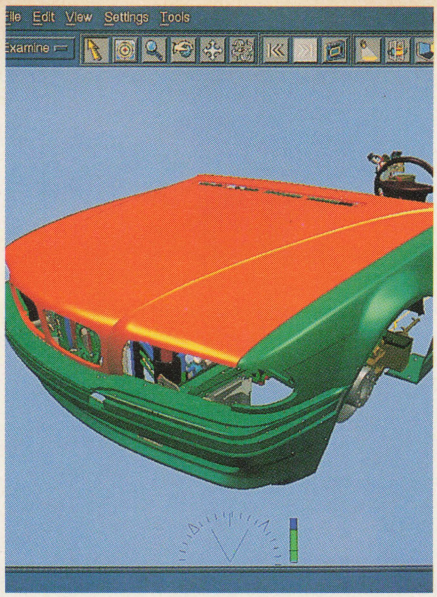
PPM expands on traditional PDM in another way, as well. Because PPM must manage a great

deal more information than just product data, it provides a mode of operation that is more visual and intuitive than the hierarchical tree structures and text-based query modes of current PCDM systems.

In Search of a Problem?

Some users see PPM as a mere marketing ploy, a way of bringing excitement to the never-glamorous arena of PDM. One person even referred to PPM as "a solution in search of a problem."

But not everyone had that reaction. A few representatives from large manufacturers at the conference offered convincing reasons why they need the functionality that PPM is said to provide. Rod Nehring, director of engineering information at Cummins Engine Co. (Columbus, IN), explained where PDM falls short and why PPM offers promise.



Enovia's VPDM software allows collaboration early in the design process at BMW.

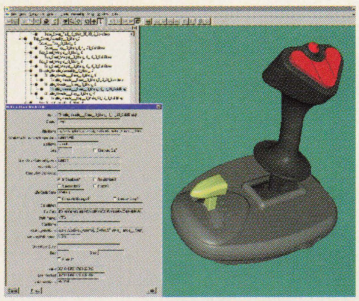
Like all manufacturing companies, Nehring says, Cummins must grapple with the challenges of shrinking time to market, lowering costs, and improving product quality. And unlike some, he says, "We don't have the luxury of creating everything from scratch. We need to focus our designers on only those parts that require creativity." Indeed, a diesel engine may contain several thousand parts, but only a small number of them can confer a competitive advantage, he explains. "Those parts are where we need to direct our design efforts. Everything else should be standard."

For that to happen, Cummins needs to create a massive library of standard parts, or come up with a knowledge-based system that can generate commonly used parts on the fly. In the first case, a traditional PDM system would suffice because it would provide access to a parts library. But the knowledge-based solution, which Cummins prefers, requires more than just access to product data.

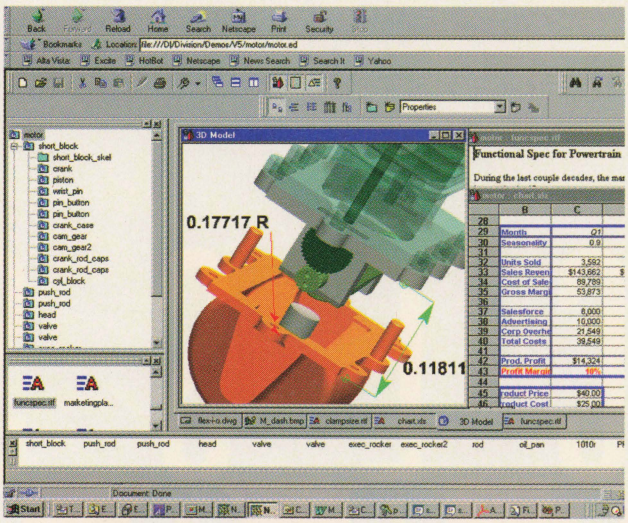
To come up with the most appropriate part for any given situation, an automated system must examine the wide range of factors that a human designer considers, such as test results from similar parts, engine-industry standards, how and where the part will be manufactured, and the experience of company experts. This differs from product data, per se, which generally refers to drawings, design geometry, assembly diagrams, bills of material, engineering change orders, and the like. This broader realm of information comes from many different phases of the product-development process, and implies knowledge rather than just facts gleaned from a document. "Regular PDM manages data," Nehring says. "We're looking into PPM because we want to map this process information into our product models."

Because PPM can encompass more activities in the product-development cycle than PDM and bring a wider range of information and knowledge to bear on a design, Cummins and perhaps other firms like it find that this capability can be a valuable asset, rather than a "solution in search of a problem."

Daratech's Jenkins agrees. Vendors aren't pushing PPM onto hapless end users, he says. Rather, companies like Cummins are driving the vendors to deliver this kind of technology. "Users have been begging the vendors to raise their sights beyond improving the modeling tools. They want vendors coming up with both technical solutions and implementation services that will help them better align the tools with their processes. This is a case of commercial-solution providers racing to catch up with what the users want."



Designers can use SDRC's MetaVPDM to quickly access CAD models and any related "metadata."



PTC's PPM initiative enables users to access product data over the network with Windchill and a standard Web browser.

What about those who fear that PPM will create more chaos in CAD/CAM and PDM operations that are already too complex? Steve Shoaf, solutions manager at Enovia, argues that these naysayers are taking too narrow a view. "Unless you get to the top level of a company, most people are just focused on their part of the process," he explains. "They may not take into account the business objectives for the company."

Different Versions, Same Story

How are vendors responding to requests for integration of process data into the design environment? Very differently. In fact, some PPM strategies don't seem to focus much on integration at all, being geared more toward boosting collaboration and innovation. Here's a summary of the PPM strategies of four different vendors who formally presented their strategies at the Daratech conference. Other companies, notably Bentley Systems with its Project Engineering Initiative and EAI with its VisEPM software, appear to working in the same direction.

• **PTC** calls its PPM initiative Product and Process Lifecycle Management (PPLM), which is based in part on the Windchill technology that PTC acquired with the purchase of Computervision back in 1998. Windchill provides the underlying Web-based architecture for PPLM that allows for the connection of all sorts of computers and operating systems. To integrate other applications as part of PPM, PTC purchased software called Info*Engine that makes data from other systems look like it's being managed by Windchill. Another key aspect of PPLM is making the manufacturing process available to the product designers. For this, PTC joined into a cooperative arrangement with Tecnomatix (Herzeliya, Israel; Novi, MI), the developer of computer-aided production engineering (CAPE) applications.

Under the terms of the PTC/Tecnomatix agreement, Tecnomatix will integrate its technology with Windchill so that all the product data Windchill holds will be seamlessly accessible to Tecnomatix's Process Planner manufacturing-process software. And all the information in the Process Planner data model, including its manufacturing intelligence, will be put into Windchill. "If a company has an enterprise-wide implementation of Windchill, Process Planner will enable every Windchill client to access, query, and take relevant information from both the product and manufacturing areas," Becker explains.

• **Unigraphics Solutions** uses the acronym PDM. But instead of Product Data Management, the letters stand for Product Development Management, which implies support for the entire product-development process, according to Raj Khoshoo, PDM business director. Khoshoo and his colleagues agree on the need to integrate manufacturing-process data with design efforts, although their way of doing that is different from PTC's. It entails creating a product data model within iMAN (the company's PPM software) that includes manufacturing-process information.

"By virtue of our years of experience with manufacturing, we think we always have had a holistic view of managing the master model," Khoshoo explains. "We are building a manufacturing data model in iMAN so that when a product design changes, the update also takes place in manufacturing. The change will be reflected in the tooling, for example, rather than just by a notification of the change sent to a manufacturing engineer."

PRODUCT PROCESS MANAGEMENT TOOLS

Project Engineering Initiative
Bentley Systems
Exton, PA
www.bentley.com
infoNOW 161

VisEPM (Visual Enterprise Process Management)
EAI
Ames, IA
www.eai.com
infoNOW 162

Enovia
IBM/Enovia Corp.
Charlotte, NC
www.enovia.com
infoNOW 163

PPLM (Product, Process Lifecycle Management)
Parametric Technology Corp.
Waltham, MA
www.ptc.com
infoNOW 164

MetaVPDM (Metaphase Virtual Product Development)
SDRC/Metaphase
Arden Hills, MN
www.metaphasetech.com
infoNOW 165

iMAN
Unigraphics Solutions
Maryland Heights, MO
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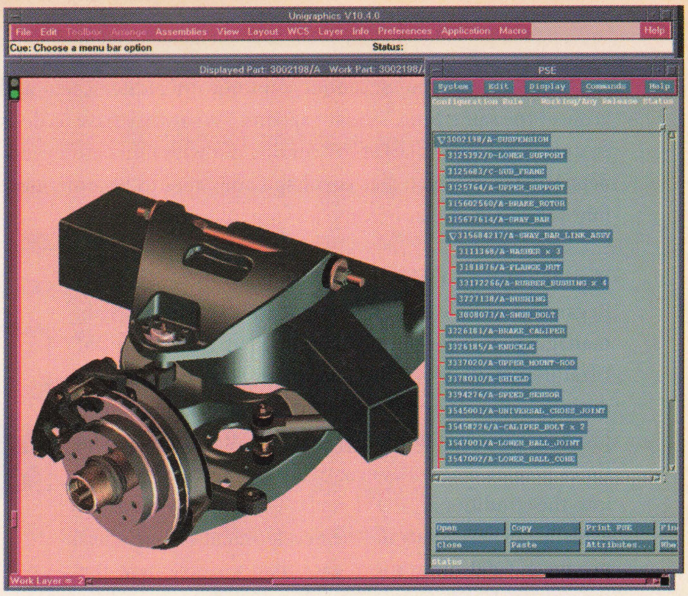
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With Unigraphics Solutions' iMAN and ProductVision, users can view the product structure and the associated geometry.

Virtual PDM

• **SDRC's Metaphase** also moves beyond traditional PDM, but its strategy is better described by the term "Virtual PDM" (VPDM) and seems more focused on collaboration than on bringing additional knowledge to bear on a design. The basic premise of VPDM is that the early phases of product development differ from the later stages, which rely on static, released documents and well-defined work processes. "The information processes in the early stages are less predictable and vary from day to day," explains Ron Schmitz, Metaphase vice president for marketing and product planning. "The well-defined workflow model of the PDM system has trouble adapting to this ad-hoc information-sharing environment. Here, technologies are needed that don't restrict, but encourage collaboration."

Metaphase is extending its PDM technology and adding some new tools to create Metaphase VPDM, or MetaVPDM, which is targeted at the cross-functional teams working in the early phases of the product-development lifecycle.

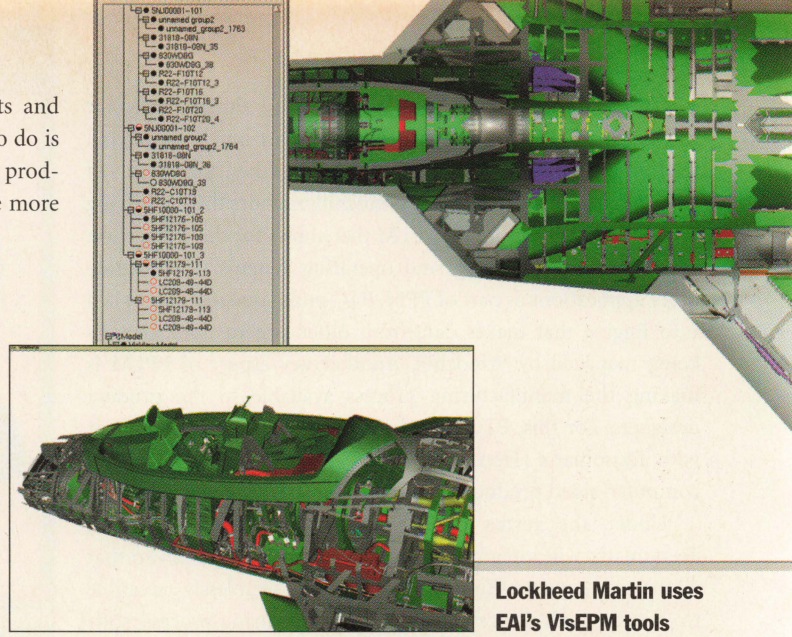
• **IBM's Enovia Corp.** has also adopted a VPDM strategy that goes beyond PDM. Like Metaphase, Enovia is designed to foster collaboration early in the product-development process. "PDM takes design data and releases it to others in the enterprise who will use it to build the product," says Shoaf. "It's a rigorous corporate process because you've got sign-offs that you need to track, and when something is discovered that requires a change to the design, there's a formal engineering-change process."

While VPDM might serve to reduce cost, the main benefit of this technology is that it fosters innovation, says Shoaf. By facilitating communication in the early, freewheeling stage of product development, more people will have input into the design. Ideally, that will lead to new ideas and innovative products.

"Leading companies cannot continue to reduce costs and grow at the same time," Shoaf explains. "What they have to do is create entirely new markets by coming out with innovative products. VPDM is targeted at enabling companies to become more innovative, which has become a competitive necessity."

Visualization's Role

Regardless of how it is implemented, PPM will clearly be managing a lot more information than PDM ever did. "Traditional PDM at the enterprise level is a tool for dealing with released data, but in the development of a product, the amount of data that gets produced is many times greater than what eventually gets released and put into the [traditional] PDM vault," Unigraphics' Khoshoo explains. "This evolution [the development of a product] produces 1000 times more data than a single item that gets released and goes to manufacturing."

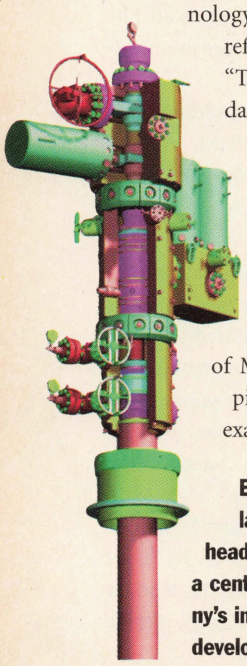


Lockheed Martin uses EAI's VisEPM tools with Dassault Systemes' Catia to optimize both product design and manufacturing processes before producing physical parts.

How do you let everyone tap into this mass of data without requiring the use of a complex, compute-intensive application? And how do you organize and present this incredible volume of information so people can find what they're looking for?

To address the first question, each vendor with a PPM (or VPDM) strategy includes an easy-to-use, Web-based viewing tool as part of its solution set. "If we're going to provide broad access to information, we also need a way to serve it up to a variety of people without having them use specific client-side software or the data authoring tool," says Lawson of PTC. Her company uses the visualization capabilities formerly sold by Division to provide a browser-based tool, called Product View, for access to product and process data. Unigraphics Solutions' viewer is called ProductVision, and is based on visualization and data-access technology from EAI. Metaphase's viewer is also built on EAI's tools, while CATweb Navigator is IBM/Enovia's browser-based viewing program.

The second issue, that of presenting great volumes of information intuitively, is driving an evolution in visualization technology beyond that offered by traditional PDM. Jenkins refers to it as a "new GUI paradigm." He explains: "The intent is to make database navigation and database interrogation as visual a process as possible. Visualization technologies are now being applied to what used to be strictly text-based, tree-structured browsers to make more kinds of data, technical and non-technical, more immediately comprehensible."



Engineers at FMC collaborated on this wellhead design using iMAN as a central part of the company's integrated product-development program.

"In the old days of PDM, users would pop up a form and do a query in text," says Schmitz of Metaphase. "Now they want to click on different pieces of a picture to find what they need." For example, in Renault's implementation of Metaphase, users can bring up an image of a car and click on a fender to get at the information they want. "It's reversing the interaction model," he says. "It used to be: query, see some text, then go look at a picture. With this new approach, you don't have to do a query. You start with a picture, and it shows you the supporting data processes. It's one of the powerful dynamics of this new approach."

"From our perspective, visualization is the cornerstone of how we present additional functionality to the end user," says Steve Bashada, director of marketing at EAI. "We believe the visual view is what people want."

Bashada points out, however, that making data accessible involves more than just serving up a nice image. "Sometimes you're not sure exactly what information you want," he says. That information could be something like minutes from a meeting about who will publish the technical documentation or a presentation given by a CEO where a new product direction happened to be mentioned. Such data would not have a logical location on the product model.

"You wouldn't know where to click on a picture of the product to start your search," Bashada says. Therefore, the) best solution for PPM data access, he believes, is the combination of a powerful Internet-based search capability with a visualization tool. In other words, you might need to do a quick search through many databases, similar to what you would do with a search engine like Yahoo!, before you even knew what you wanted to look at. EAI recently filled in this side of the equation with eVis, an Internet-based search technology that allows users to search PDM, CAD/CAM, and other databases quickly.

Until PPM becomes more established, there will continue to be debate about how it should be defined, applied, and developed. But one thing seems clear. Traditional PDM can take companies only so far. To make the next big leap in competitiveness, they require technologies that will improve collaboration and innovation, not just to get products to market faster, but to get the *right* products to market faster. And tools that help meet those goals are worth investigating.

Caren Potter is a contributing editor of Computer Graphics World. *She can be reached at cpotter@northcoast.com.*

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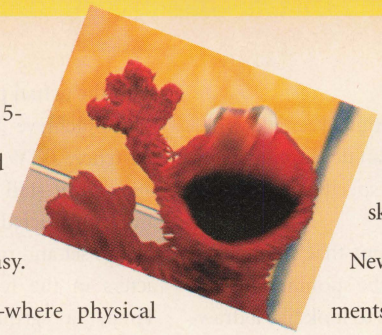
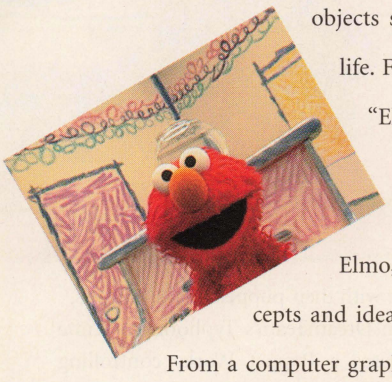
ELMO'S WORLD

Where physical objects spring to life as real-time 3D animations

BY KAREN MOLTENBREY



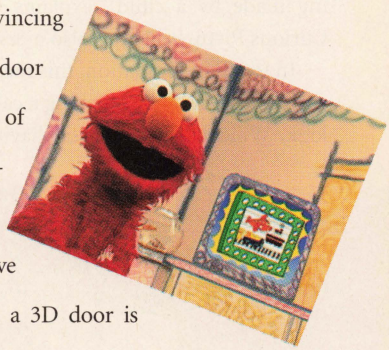
In "Elmo's World," a daily 15-minute segment that debuted on this season's *Sesame Street*, there is no line separating reality from fantasy. It's a place where anything can happen—where physical objects suddenly spring to animated life. From the viewers' perspective, "Elmo's World" is an imaginary place created in crayon by the lovable child-like character Elmo, who explores various concepts and ideas in his animated playroom.

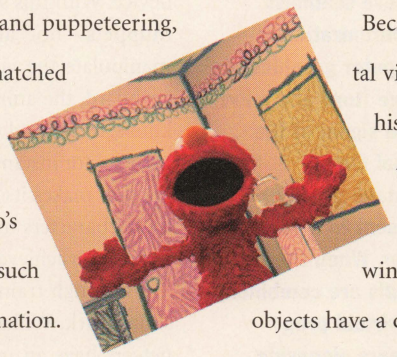


From a computer graphics perspective, the segment is a unique mixture of real-time animation and puppeteering, in which the two techniques are mixed and matched in perfect synchronization during a live shoot and post production.

Like many other *Sesame Street* scenes, "Elmo's World" comprises a mixture of real elements (such as puppets, people, and animals) and animation. However, the segment achieves a unique look as real objects suddenly become 3D animations (which look more like classic 2D animated objects) and vice versa, during taping.

"'Elmo's World' consists of characters that exist virtually and in the real world. When an effect cannot be achieved using a real object, then a virtual replica is used," says Lewis Kofsky, technical director at Curious Pictures in New York, which produces the virtual puppet segments. "We are able to use the best of both worlds to accomplish convincing effects." For instance, when a door opens and spills a closet full of balls on top of Elmo, an actual set door and real props are used. When a locomotive bursts through the doorway, a 3D door is inserted during the shoot.





Because the group opted not to use a fully digital virtual set, the director has more flexibility in his use of props, Kofsky says. For instance, there are certain props that appear at least once every episode—such as the door, window, television, and drawer. Since these objects have a dual existence (real and virtual), they can be used as a virtual background prop as well as a real object with which a character can interact more realistically. For instance, to end each episode, Elmo pounds out a tune on an actual piano, but a virtual model of the instrument is shown bending and moving in other scenes.

©1999 CTW. Images courtesy of Curious Pictures.

Discovering a New World

The concept for "Elmo's World" was born about a year ago, when Children's Television Workshop (CTW) began developing a new segment for *Sesame Street* that was geared specifically for toddlers and would feature a unique look.

"We were trying to create an environment that stems from Elmo's imagination, and like Elmo, it had to be spontaneous and have personality, but at the same time, it had to look like a drawing made by a child," explains CG director Mo Willems of Curious Pictures, who is also a *Sesame Street* writer.

In terms of animation, this meant infusing a personality into various objects and achieving a cartoon-like stretch-and-squash look, Willems says, but still having those objects interact live with the actual puppets.

To achieve this dual existence, CTW and *Sesame Street* staff designed and constructed the segment's set and main characters in the real world. Then, a group from Curious Pictures photographed and measured the set and objects, and re-created them digitally in the CG world. "The most challenging aspect was to achieve the same physical motion and personality from our computer graphics that the puppeteers achieve with their puppets," says Willems.

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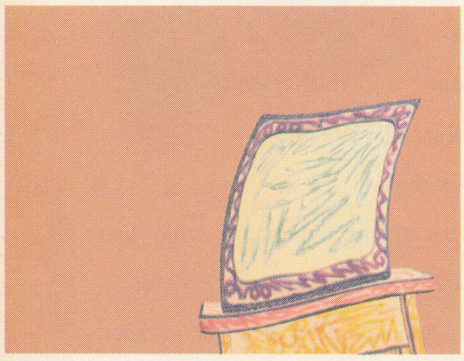


"Elmo's World" contains a unique blend of real and virtual elements that give the segment its special look. To achieve seamless synchronization, a computer graphics image (top) and a live video signal of the actual Elmo on stage (middle) are sent to a video mixer. When the two signals are combined, the virtual prop appears alongside the actual puppet in the completed scene (bottom).

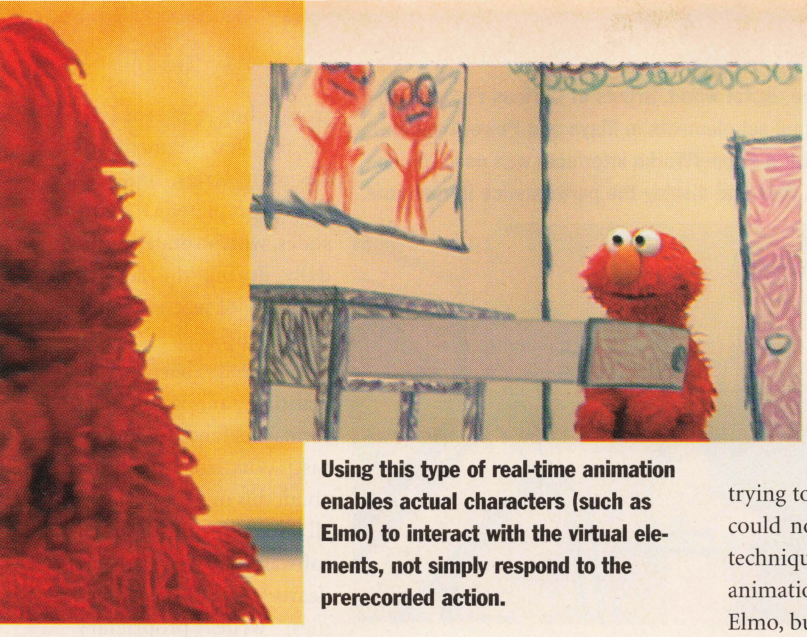
The solution was found in DreamTeam's Typhoon real-time animation software, which uses a Puppet Works controlling device. With this system, puppeteers who usually control real-life muppets—not animators or performance-capture artists—manipulate the virtual characters. Instead of using a mouse or keyboard, the animator-puppeteers physically operate a series of knobs, levers, and sliders that control the virtual characters' movements—for instance, one lever may control a character's leg, while another makes its belly bulge. "They came up with ways to make these characters move that we never imagined and that we could never have achieved using traditional animators," he says.

Although training puppeteers to become animators required some work, Willems says that was not a big issue. "These puppeteers have an incredible sense of timing and a great sense of character. And that's the advantage to 'Elmo's World'—these puppeteers were already accomplished performers," he says. "I think we ended up with a much better result using them. Our job was to make the virtual puppets as puppeteer-friendly as possible. *Sesame Street* has this amazing resource, and we wanted to use that resource as fully as possible."

Setting Up

The creation of Elmo's digital world begins in Alias|Wavefront's Maya and PowerAnimator running on an SGI Octane, where the virtual elements are modeled and used as reference objects during the initial taping of the segment. For texturing, the Curious Pictures team photographs the real set elements and digitally scans and color-corrects them with Adobe Systems' Photoshop, along with Maya and PowerAnimator, to match the real and CG objects.

The group from Curious Pictures then packs up their SGI workstations and heads to *Sesame Street*, where the actual "Elmo's World" set is located. "Depending on which scene they are taping, [the producers] either use the actual characters that are on the stage or we replace one of them with a virtual character," Kofsky says.



Using this type of real-time animation enables actual characters (such as Elmo) to interact with the virtual elements, not simply respond to the prerecorded action.

For instance, in a scene where a television set comes bounding onto the stage, the film crew frames the Elmo puppet and a real television prop in the video camera, which sends a video signal to a monitor. A virtual prop is positioned over the actual prop, which is removed from the stage. An output signal is then sent from the computer into a video mixer. "So what appears on the monitor is Elmo next to the television. But when you look at the actual set, all you see is Elmo," explains Kofsky. "In essence, we are mixing a computer signal with a live video signal, and that's how the two types of characters can interact."

The entire scene is recorded live in Typhoon running on the Octane, where the CG reference objects are animated in real time with the Elmo puppet to ensure synchronization between the real and virtual characters. Typhoon was first shipped in mid-1996 for the "CyberCindy" show on MTV and has since been used for live-to-air animation, integration of virtual characters into virtual sets, and post-production applications.

Basically, Typhoon's role in the production of "Elmo's World" is twofold: The software captures the motion data from the performance and displays the performance in real time.

The recorded scene is then transferred back into PowerAnimator directly through Typhoon for high-quality post-production rendering of the animations. "We clean up the animation—smooth it out, if there are any glitches—and sometimes make small directorial changes in the animation afterward," Kofsky says. "It's great to have all the freedom of post production mixed with a live performance."

Curious Pictures composited about half the 10 segments in Adobe After Effects and Maya Composer, while the remaining segments were composited by SMA Realtime (New York) using Avid's Media Illusion and Quantel's Hal Express and Henry. "Compositing the digital textures to match the colors and the lighting of the set exactly is tricky," says Kofsky. "The whole point is to mix and match virtual and actual elements seamlessly, so the audience doesn't know when the real object is being used. We can't break the illusion that this is a magical world where these characters can do anything."

Video editing is performed by John Tierney at IXL (New York) using Avid's Media Composer.

Truly Unique

According to Kofsky, "Elmo's World" is a prime example of creativity rather than technology driving the bus. "We didn't just do things virtually because we could. What dictated whether we used real or virtual objects was the particular concept the directors were trying to convey," he explains. In turn, this produced a look that could not have been achieved using other forms of animation techniques. With prerecorded animation, for instance, a digital animation file would have been mixed with the video signal of Elmo, but the Elmo puppeteer would have had to react to—and not with—the animation.

"What we did was send a digital animation signal, but at the other end of that signal were two puppeteers controlling the interaction with controls and sliders," Kofsky says. "Because the puppeteers controlling Elmo could talk with the puppeteers controlling the virtual elements, they could work out their performance, and the director could direct both of them, changing the performance as it developed."

Using such a diverse mix of technologies presented some unique challenges, since the technology in the pipeline originated with so many different kinds of products—Puppet Works, Typhoon, SGI workstations, NT workstations, Macintoshes, Maya, and PowerAnimator—that were never linked up before at Curious Pictures. In addition, a live, non-digital

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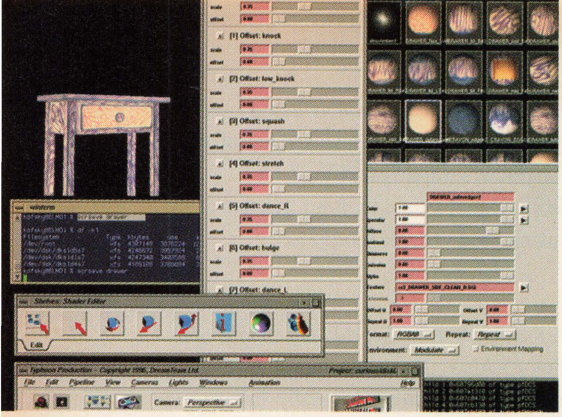

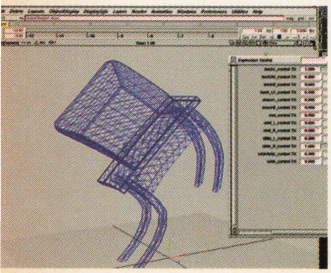

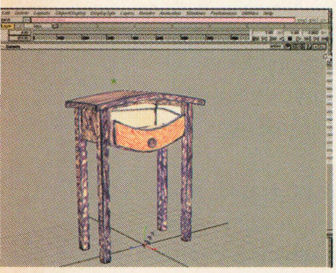

To create the digital world, artists at Curious Pictures duplicated actual set elements in Maya and PowerAnimator. Typhoon (with a PuppetWorks interface) was used to capture motion data and display the performance in real time.

set was a new environment for the Curious Pictures animators, who were used to keyframing sequences at their desks, at their own pace. "Some shots would require up to 15 takes, so we would have to try different performances on the set and change the characters until it was correct," Kofsky adds.

Using this unique animation technique, the group can produce an average of one "Elmo's World" segment every 15 days—one week for preproduction modeling/texturing, one day for the live shoot, and one week for post production. Last August, the group began recording the first few segments of the pilot series, and has since completed 10 episodes, which rotate to run daily during the last 15 minutes of each *Sesame Street* show.

"There's been little real-time animation performance done [for broadcast]. What's really exciting about this one is that it was all done using off-the-shelf software. Typically, for endeavors like this, companies write proprietary code. We just bought the software, set it up, and produced a show," Kofsky says. "It was done on a lean budget, and our method ultimately offered a quick, simple solution."

Adds Willems: "I believe 'Elmo's World' is definitely pushing technology in terms of virtual sets and real-time animation. *Sesame Street* has a great tradition of accomplishing the untried, which makes it the perfect environment in which to be playing with this technology."

Karen Moltenbrey is an associate editor for Computer Graphics World.

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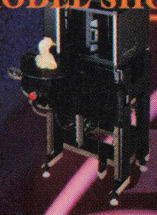

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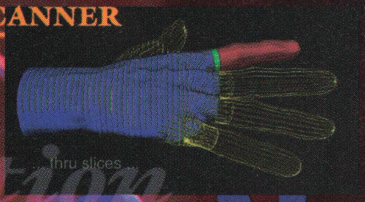

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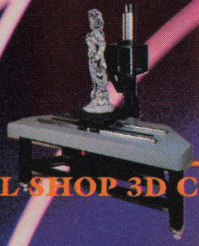

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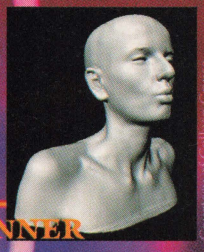

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ANIMATORS TURN 3D JIGSAW PUZZLES INTO INTERACTIVE ADVENTURES

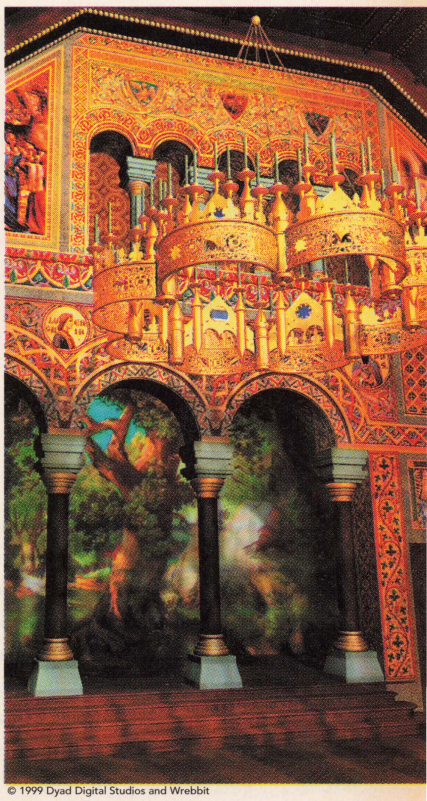
BY KAREN MOLTENBREY

While most people turn to computer graphics to *solve* puzzling problems, the animators and modelers at Dyad Digital Studios in Montreal use digital imagery to *create* them. Specifically, Dyad has taken the Wrebbit company's three-dimensional cardboard-and-foam jigsaw puzzles and transformed them into the first interactive computer-based 3D puzzles.

Just as Wrebbit (Montreal) revolutionized the jigsaw world in the early '90s with its Puzz-3D projects, Dyad redefined that 3D puzzle genre a few years later when it transformed one of the physical 3D games onto a CD-ROM for digital play. The transition occurred after Michael Donovan, a computer programmer with a background in artificial intelligence and software design, pieced together one of Wrebbit's 3D cardboard creations.

"I wanted to go inside [the puzzle's medieval fortress], see what was in the towers, and learn about the history of the building," he says. In 1996, Donovan created a rudimentary computerized prototype

While the main objective of the Puzz-3D CD-ROM games is to piece together the puzzle, once that is complete, the real adventure begins. To reward the player, animators created a virtual tour of the structure, complete with video clips of period characters, as well as additional games and mysteries to be solved.



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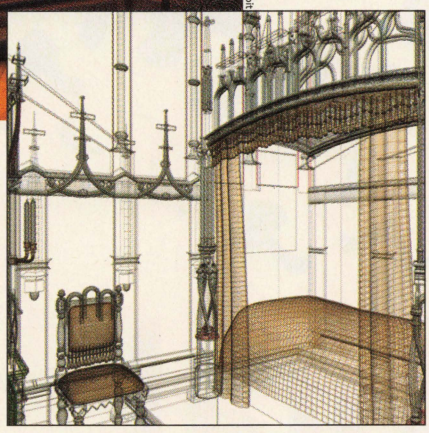


Because of its size, the *Neuschwanstein Bavarian Castle* was built as eight separate models, each ranging in size from 1 million to 2.5 million polygons. To achieve the richness of the imagery, such as in this scene (above) and in wireframe format (right), the artists created more than 400 textures, with some source images as large as 200MB.

of the puzzle and showed it to Wrebbit, which was considering an electronic venue. Soon thereafter, Donovan signed a contract with the gamemaker to create an interactive 3D CD-ROM version of the Puzz-3D *Notre Dame Cathedral.*

That project, like the two others that followed—*Victorian Mansion* and *Neuschwanstein Bavarian Castle*—went well beyond the process of assembling a puzzle on the computer. The player must first construct the puzzle, using a 2D worktable to build sections (floors, walls, roof), then move them into the 3D construction area for further assembly. Once the structure is complete, the real 3D adventure begins, as the player navigates the highly detailed interior spaces in virtual reality and partakes in interactive games.

Building Blocks

When Dyad began assembling its first 3D CG puzzle, a few virtual jigsaw puzzles existed, but none offered the complexity sought by Donovan. As a result, Dyad developed a 3D game engine with proprietary code that would allow for high-quality real-time display and rotation of complex geometric shapes. The technology also had to provide for cross-platform use, since the games were to be ported to both Macintosh and Windows environments.

"It wasn't just a question of developing the graphics and the game engine. It was first a question of how can this be done," says Donovan. "Making something in 3D is usually pretty complex; not everyone has a sense of depth and the ability to do spatial relations on the computer."

Adds programmer Robert Donovan: "We knew these games would attract people who use their computers for word processing and spreadsheets, so it had to be simple to use and install. We wanted our grandmothers to be able to play."

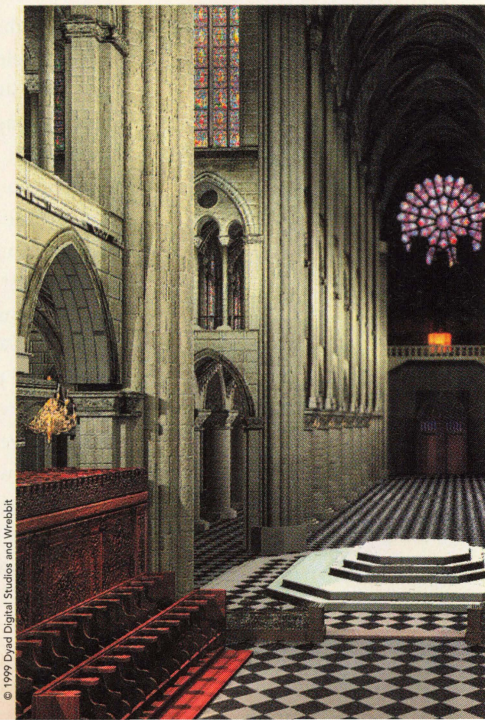
Creating the logistical groundwork so the puzzles could be constructed in 3D CGI consumed most of the development time—initially. But an equally, if not more, daunting task was the overall creation of each game—especially designing the exploration phases and creating the video clips that bring the structure's history to life. "The exploration part is your reward for completing the puzzle," Michael Donovan says, a concept that was planned from the beginning but grew beyond the initial intention. "The more [information] we had, the more we wanted to include."

To lay the foundation for this second phase required extensive research. For instance, the group photographed "almost every wall of the [actual] Notre Dame Cathedral, and almost everything in it" as a basis for the structure and textures, Michael Donovan notes. The team also researched the church's history, contemporary history, and Victor Hugo's *The Hunchback of Notre Dame.*

"We attempt to be as accurate as possible for the buildings and places we re-create," he adds. "The stories that take place inside are directly related to the building, and there are little puzzles and mysteries, too, that coincide to the story."

When the researchers are lucky enough to find original architectural plans, often the material is 50 to 150 years old, so there is a lot of discrepancy between the plans and the actual construction. The chapel inside the Neuschwanstein Castle was another case entirely: It was never completed.

To re-create these structures, artists at Dyad built the 3D geometry using Auto•des•sys' form•Z modeling software



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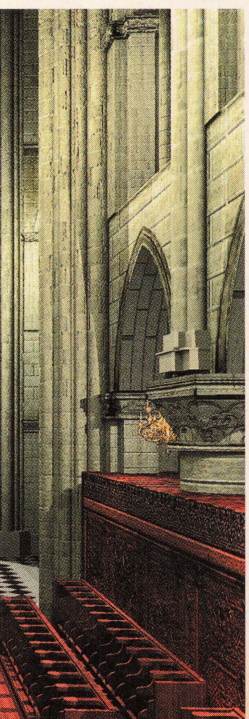
running on Power Macintoshes. "Buildings like the cathedral and castle have a lot of complex architectural features, such as crossed arches," says art director Jean-Alexis Doyon. "But we're able to model them in solid form quickly and precisely by using form•Z."

Meanwhile, another group of artists, led by graphic designer Eric Gagnon, performed the 2D texturing in Adobe Systems' Photoshop and Illustrator, using a variety of visual sources (including postcards, photographs, and book illustrations) as a springboard for artistic interpretation. "Most of the inside pictures of the buildings were taken at strange angles, warping the textures to where we had to redo them completely," says Gagnon.

The textures were applied to the 3D geometry with Play's Electric Image, which was also used to create the lighting effects and the VR camera animations for the virtual visits inside the various rooms. "To wrap some of the intricate textures we created onto complex shapes, we deform the textures in such a way that when they are wrapped, they look fine," Gagnon says.

Adds Doyon: "One of our biggest obstacles with *Neuschwanstein Castle* was the frescoes. The castle contains many beautiful paintings with a lot of gold-leaf detailing, and at first, we couldn't make the gold look right. Because the specularity of the gold leaf was the same as the painted elements of the texture map, the gold looked like flat yellow paint."

To rectify this problem, the art director created a gold-based material shader, which the group applied to the geometry, to make it react in a way similar to actual gold leaf. The artists then applied the fresco textures in successive stages: first, a diffuse map, then a transparency map to let the gold of the shader shine through, followed by a specular map to produce the paint matte and the gold-leaf reflectivity, and finally, a displacement map for the embossed elements.



Creating this interior imagery for the *Notre Dame Cathedral* puzzle required extensive research by Dyad artists, who also photographed the interior of the actual cathedral to ensure accuracy.

3D Building

With form•Z and Electric Image, the artists rendered scenes containing upwards of 2 million polygons, 200 textures and 70 lights—without difficulty. "And we still haven't reached the choke point yet," says Doyon. "Using Electric Image is one reason why we are able to incorporate camera animations in our models without using a rendering farm. We *are* the farm."

For the first puzzle, *Notre Dame Cathedral*, the artists used Strata's (St. George, UT) Studio Pro for the modeling and rendering, and Macromedia's (San Francisco) Director for the VR exploration. But when it came time to render the project, the geometry proved too extensive for the software, so the artists adjusted the models accordingly to complete the task for the initial version of the game.

Because the group is able to develop the games on a Mac platform—instead of an expensive high-end graphics workstation—and uses off-the-shelf software, it can produce striking graphics fairly inexpensively, Doyon says.

To augment the imagery in the VR adventure, a player can use hot spots inside the structure to trigger QuickTime movie clips written by Dyad that are based on the group's earlier research. Fully costumed live actors were filmed against a blue screen, then the artists digitized and composited the material with Adobe's Premiere and After Effects before incorporating it into the movie. Adding further atmosphere are the music and sound effects, all produced in-house.

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The artists built *Victorian Mansion* as one large model, with parts and furniture made by different artists imported into the main model. In all, the game contains more than 6 million polygons, 250 lights and light flares, and more than 150 textures.

Future Construction

Prior to breaking ground on the *Cathedral* project, Dyad was a small upstart multimedia company that dabbled in commercials work. But once it started piecing together the tools needed to complete its first digital puzzle, there was no slowing it down. In fact, the game was originally conceived as 2D, with a fake 3D perspective, but soon took on all new proportions.

Michael Donovan attributes the success of the CG puzzles to their nonviolent nature, "and it's one of the few games that we can honestly say is family-oriented. Some children's games can also be enjoyed by adults, but this one is truly trans-generational."

Currently, a fourth, undisclosed game title is under way at Dyad. "It's not going to be a building, but it will be very entertaining," Donovan promises.

Karen Moltenbrey is an associate editor for Computer Graphics World.

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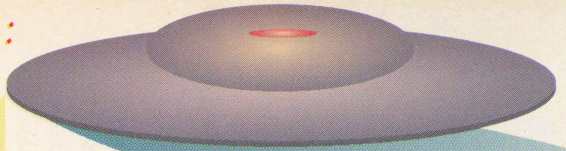

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Digital Storytelling

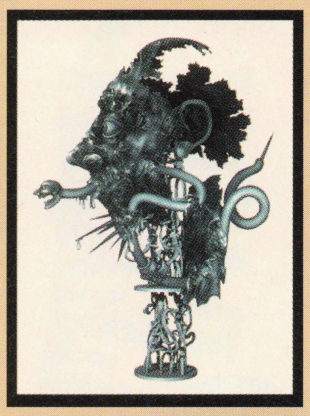
During the past few decades, digital creations have evolved from primitive works to those commanding serious attention within the art and theater communities. The new level of artistic maturity is especially evident in this year's selections featured in the Siggraph Art Gallery and Computer Animation Festival.

TechnoOasis, the electronic arts exhibit, will display more than 100 works, including digital paintings, drawings, sculpture, Web-based projects, and much more. "We have a mature show this year," says Marla Schweppe, art gallery chairwoman. "Many of the works will find their way into museums and galleries around the world."

To provide further artistic insight to the works, guides will provide tours through the exhibit during the Siggraph conference.

At the animation festival, 42 juried pieces—selected for innovation in digital storytelling—will

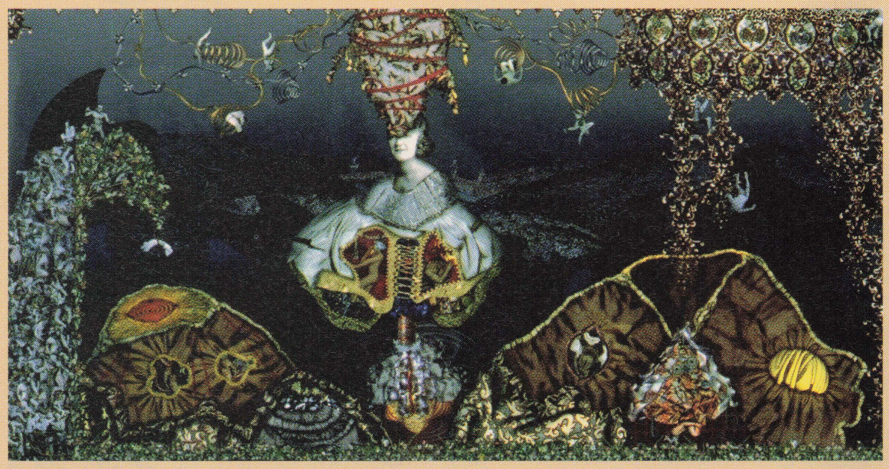
continued on page 88



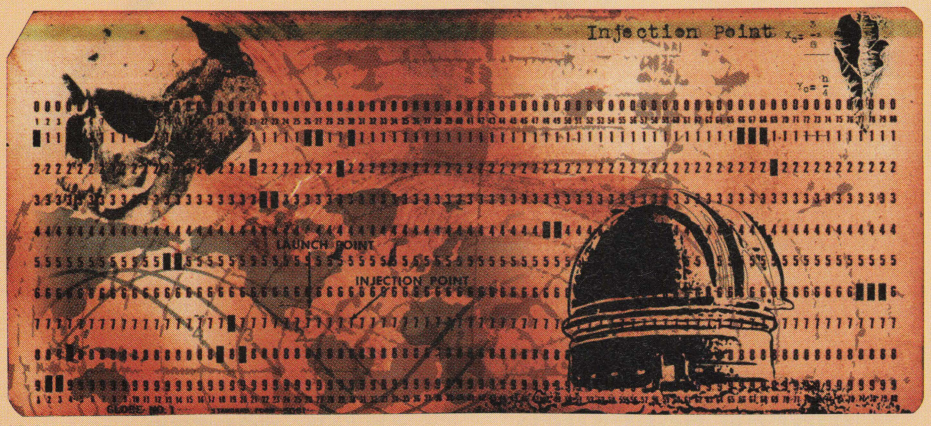
"Dark Monarch Lingering Shroud," Andrew Polk

"Intersections #1," Thomas Porett

"Fava Milagro," Anna Chupa



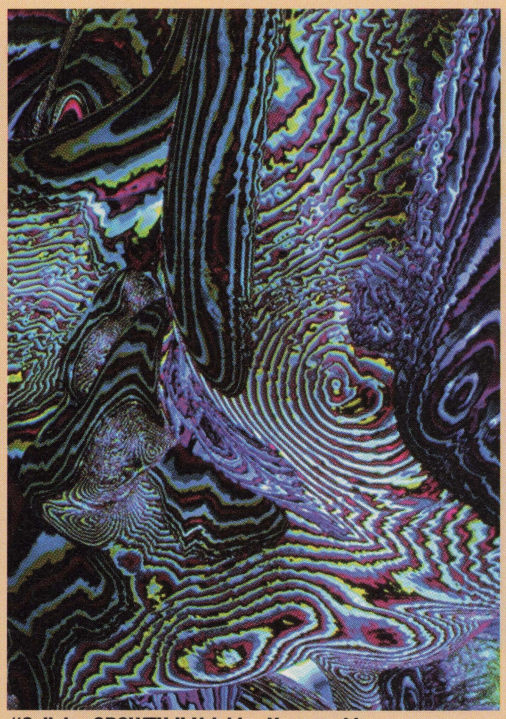
"The Assumption of Pleasure," Anna Ullrich



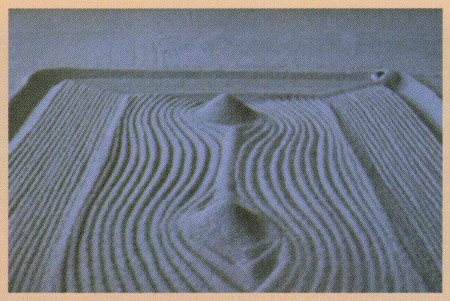
"Injection Point," Peter Patchen

"Colour and Drawing: From a Garden Table," James Faure Walker

FOLIO

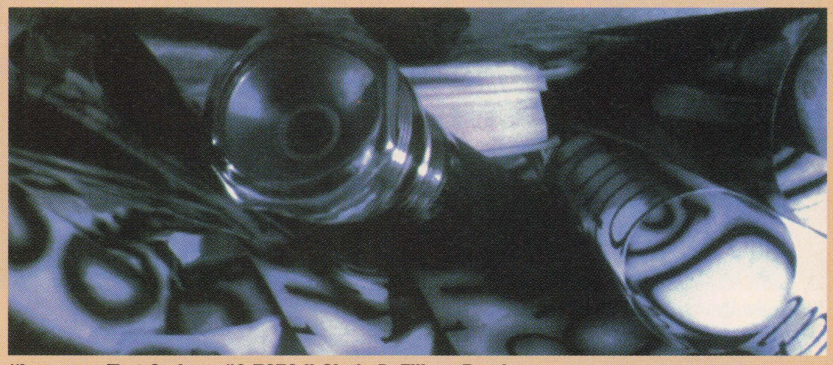


"Cellular GROWTH," Yoichiro Kawaguchi

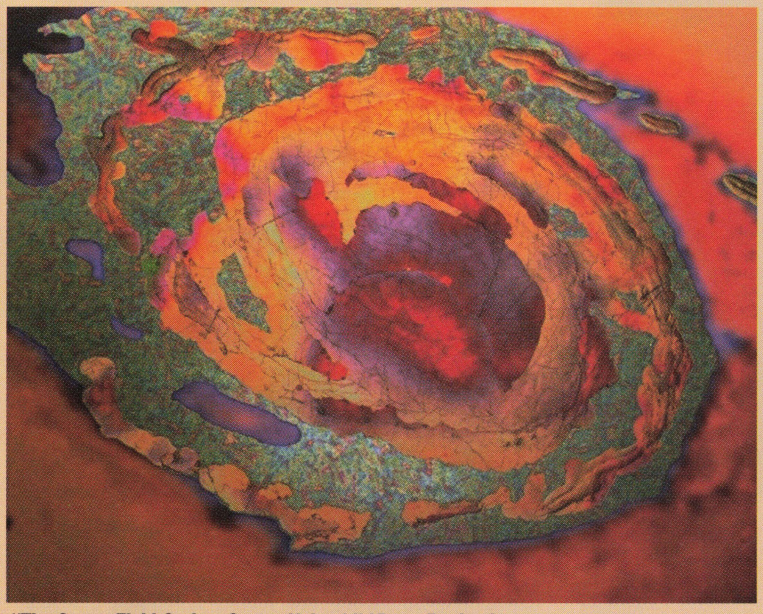


"Sisyphus," Jean-Pierre Hébert

"Inbetween1," Mark Marcin

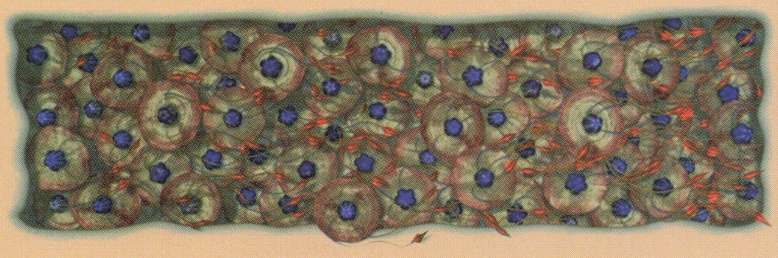


"Language/Text Series—#6-7278," Gloria DeFilipps Brush



"The Space Field Series: Comet Nebual," Victor Raphael

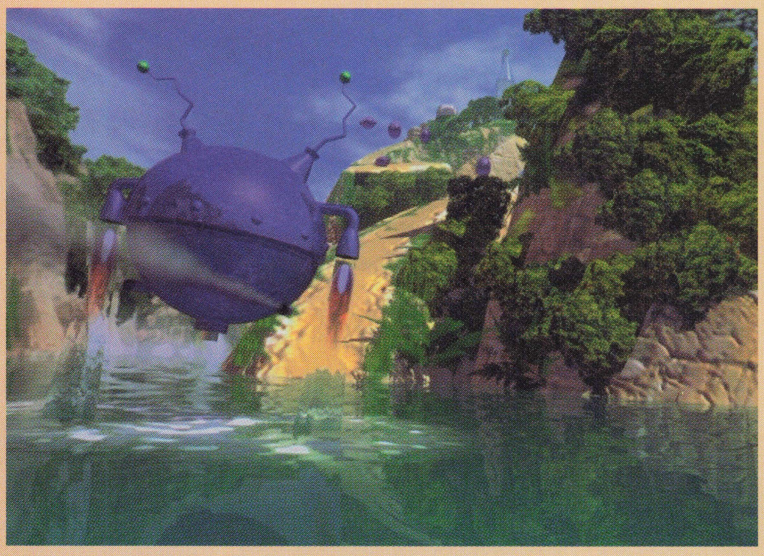
"Inside Light," Harvey Goldman



"98.3," Kenneth A. Huff

"Genroku-Ryoran," NHK Enterprises 21

"Sea Dance," Yoichiro Kawaguchi



"Ribena Cyberries," Animation Research Limited

"Exotica," Yoichiro Kawaguchi

continued from page 86

be shown in the Siggraph Electronic Theater during matinee and evening performances. A broader selection, highlighting more than 120 submissions, will be shown in the Animation Theaters. "Digital storytelling is the new frontier of integrated multimedia, which, along with computer graphics, has transformed the way we communicate at a fundamental level," says Brian Blau, animation festival chairman.

Throughout the year, *Computer Graphics World* has already published some of the images being showcased at Siggraph's gallery and theater—such as those from the film *Star Wars Episode I: The Phantom Menace* (pg. 54)—during ongoing coverage of CG innovation throughout various industries. A small sampling of images that have not previously appeared in the magazine are featured in these pages. —*Karen Moltenbrey*

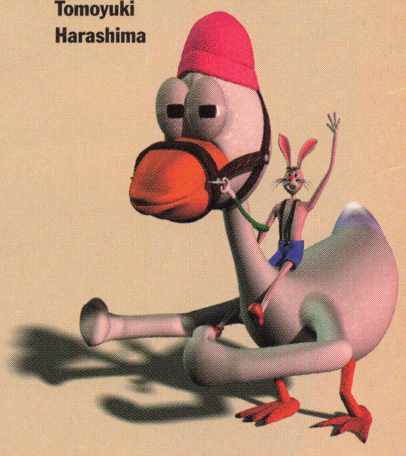
F O L I O

"CarouseL," Hiroshi Shiokawa

"Frisk Spider," Glassworks, Ltd.

"The Fort at Mashantucket," Raymond Doherty

"The Duck Father," Tomoyuki Harashima



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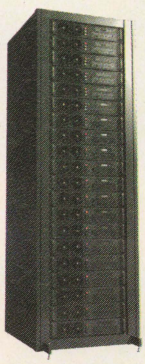

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BROADCAST

A New Driving Experience

Pontiac 'gets real' with two all-digital television commercials

BY AUDREY DOYLE

©1999 General Motors. Image courtesy of Digital Domain.

Reflection quality was just one reason among many for using CG vehicles in Digital Domain's commercials for Pontiac.

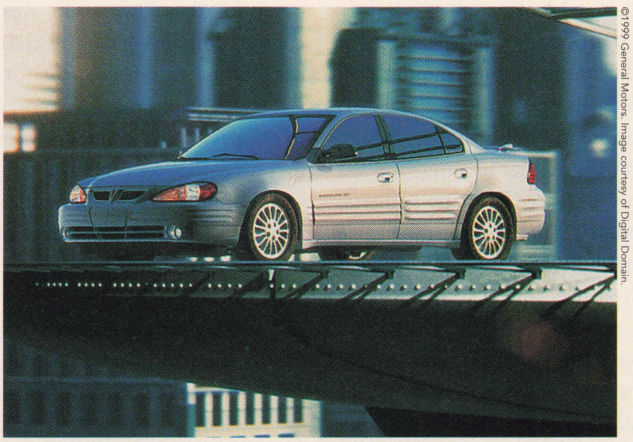
It's not always easy to illustrate a concept, such as the ruggedness and durability of a car. For D'Arcy Masius Benton & Bowles, the agency in charge of a two-spot campaign for General Motors' Pontiac Grand Am GT and SE, the solution was to show the cars moving through harsh, metal environments, a novel idea designed to emphasize the models' "SolidForm Design" and their ability to withstand severe driving conditions. For Digital Domain, the studio hired to create the commercials, the solution was just as unconventional.

"We created not just the cars in the computer, but the environments, too," says Digital Domain's (DD; Venice, CA) Ray Giarratana, who directed the 30-second spots, called "Metal Desert" and "Metal City." "It's not new to show CG cars in commercials; our studio has done it before," he says. "But it is unusual to have a CG car driving around in a computer-generated environment. Actually, I'm not sure it's even been done before in a commercial."

According to Giarratana, prior to deciding that all-CG commercials were the way to go, the DD crew discussed various approaches to achieving the ad agency's sought-after look. "Should we use real cars, miniatures, CG cars, real environments, CG environments—we went around and around as to how to make the shots work," he recalls. Shortly after discussions began, the group agreed that the steel environments should be computer-generated.

As for the cars, Giarratana says DD knew that using physical versions of the automobiles—either the actual vehicles or miniature models—would present a number of challenges. Although compositing actual cars into CG environments could be done, getting them to look right would have been difficult at best.

"It would have been so much grief. We would have had to deal with camera-tracking issues, and making sure it looked like the car tires were really touching the ground. We also would have had to deal with reflections and shadows, and getting them to look just right. Plus, it meant we would have had to pretty much do two complete productions: a live session and a post session," he says. "We thought it would solve so many problems by just doing it all in one camera."



©1999 General Motors. Image courtesy of Digital Domain.

Instead of taking the new Pontiac Grand Ams to the streets, Digital Domain took them to the computer, creating digital environments for the cars to traverse.

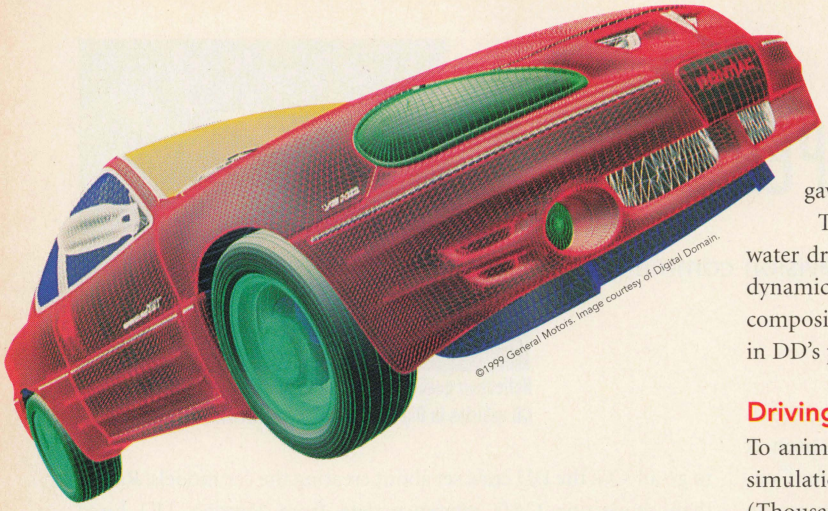
After the decision was made to go all-CG, the DD crew set about creating the car models. Rather than requesting CAD reference data from Pontiac, DD hired Viewpoint Digital (Orem, UT) to digitize a full-scale Grand Am GT and SE.

"Once we got the data, we went through lots of massaging to make it photo-renderable. What we got from Viewpoint was a big bunch of geometry, and we had to assign a zillion surfaces to it. We had to make sure it reflected the right way and that it was mapped, colored, and lit the right way," Giarratana says. "It took endless details to make it go from a bunch of polygons to something that looked like a car."

The car models were built, rendered, and lit in NewTek's (San Antonio, TX) LightWave running on Carrera Computers' (Laguna Hill, CA) DEC Alphas. In most of the shots, the car models were approximately 500,000 polygons in size. "That's one of the reasons we used the LightWave renderer for this project: because it handles large amounts of polygons incredibly well and efficiently," comments Eric Barba, the CG supervisor and digital director of photography on the two spots. "It would have been very difficult to do this type of work in any other package."

The next step was creating the environments. The scenery in "Metal Desert," the Grand Am GT spot, includes everything from shiny metal cacti to a barbed wire-like tumbleweed. The landscape in "Metal City," used for the SE model, depicts metal skyscrapers and other shiny buildings; it also includes a mercury-like puddle through which the car drives. While both environments are filled with metallic-like objects, each presented unique challenges.

"In 'Desert,' we had to make a lot of design decisions. For instance, if you look at the tumbleweed, it doesn't really look exactly like a metal version of a tumbleweed. It rolls like a tumbleweed, but it's not a big Brillo pad; it's more stylized," Giarratana says. "Before we could build all the elements in the desert environment, we had to decide what they were and why they were. The agency gave us a pretty broad palette. They just said, 'Here, it's metal and it's tough. Go.' "



Digital Domain began the cars' production cycles using a digital scan of actual Grand Ams, then built, modeled, and lit the CG images in NewTek's LightWave.

Like the car, the environments in "Desert" and "Metal City" were modeled, rendered, and lit in LightWave, while texturing was done primarily in Adobe Systems' (San Jose, CA) Photoshop, although LightWave was also used for "Desert." The desert sky was also a Photoshop creation. "I was on a shoot for another commercial, and there was a beautiful sunset that I shot, thinking we'd need it at a later date, and a few months later we were given this job," Barba recalls. He gave the photos to a DD matte painter, who scanned them into a Mac and then tiled, retouched, and color-corrected them in Photoshop on an SGI (Mountain View, CA) workstation.

As for "Metal City," Giarratana says the primary challenge was dealing with the volume of details that had to be modeled, rendered, lit, and textured. "It was never 'Chrome City.' It wasn't 'Iron City.' It was 'Metal City.' And that meant we had to apply all different types of metal all over the city. Not just on the buildings, but on the street details, the road surfaces, everything."

Although metal is a relatively easy texture to create digitally, Giarratana says it was difficult to create the variety of metals necessary for "City." But rather than create a giant metal junkyard, the team used certain metals to signify particular areas of the city. For instance, for industrial areas, they used heavy irons, rusted metals, and aluminum. In other parts of the city, such as the financial district, they went with a more brushed-metal look.

Some of the metal textures in "City" began as photos of bits of metal the DD team gathered from the studio's model shop as well as from junkyards and elsewhere. The photos were then scanned into a Mac, color-corrected and enhanced in Photoshop on an Intel PC, and applied to the appropriate models. Other textures, applied to the buildings in the background, were created by matte painters. "They took a rendered piece of geometry, a flat view of the building model, and painted on that in Photoshop," explains Barba. "They gave the mattes back to the CG artists, and then we mapped the textures onto our geometry."

According to Barba, each scene consisted of approximately 1.5 million polygons. The DD team rendered between 10 and 15 elements for each shot and used the studio's proprietary Nuke software to composite the multiple elements. Rendering times ranged from 10 minutes or so for a motion-blurred background to an hour or more for the fully ray-traced hero car shots. "It was very difficult to make it look as though these scenes were shot with a real camera," says Barba. "It was a combination of Nuke and the LightWave renderer that gave us that photo-real and artistic look."

To create the puddle and the accompanying splash and water droplets in the "City" spot, the team used RealFlow, a fluid dynamics simulator created by Next Limit (Madrid, Spain). All compositing was completed in Discreet's (Montreal) Inferno and in DD's proprietary Nuke software.

Driving the Cars

To animate the cars, the group used ReelMotion, a physics-based simulation and animation tool created by Motional Realms (Thousand Oaks, CA). After importing the LightWave scenes into ReelMotion, the DD animators simply input a series of parameters, including the car's weight, tire type, and suspension. Then, using a mouse, they "drove" the cars through the environments, and ReelMotion accurately animated the movement in real time, taking into consideration the positions of the cars and tires, the way the suspension reacted to the terrain, and other factors. When they were pleased with the animation, the animators loaded the data into LightWave as motion files.

"It's kind of like motion-capturing people, but in this case it motion-captures vehicles," says Barba. "We even played around with it a little to see how the cars would handle with a loose suspension versus a tighter suspension."

"At the beginning, I was a little concerned about being able to make the car handle correctly," admits Giarratana. "Luckily, our team really nailed it with ReelMotion." The group was even able to incorporate tricks ad agencies use on real cars—for instance, to make a car look a little sexier, sandbags are sometimes placed in the trunk to make the body ride lower to the street. "We had the same ability with ReelMotion. And the agency and the client were able to talk about the CG cars almost in the same terms as real cars to address the same things they would if the cars weren't CG," he says.

While most of the shots were accomplished using ReelMotion, some were hand-animated instead to achieve an exaggerated look.

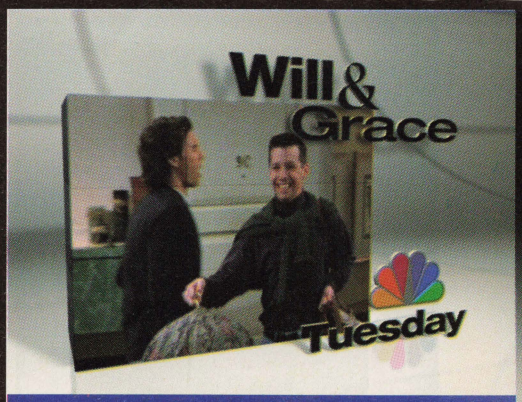
Deciding to create the cars and the environments on the computer for these two spots was a bold and innovative move on Digital Domain's part, but Giarratana stresses that the studio did not choose this route just for the sake of exploring uncharted waters. "Car photography and cinematography is a real art form. In the past, we've created some CG cars and shown car advertisers that we can do a photo-real CG car, given the right reason to do it.

"Doing the environments in CG, too, was the next step, but there was also a real reason to do it this way," he concludes. "It was the best way to go."

Audrey Doyle is a Computer Graphics World *contributing editor and former editor-in-chief of* Digital Magic. *Based in Boston, she can be reached at audreyd@mediaone.net.*

Key Tools **LightWave**, NewTek (www.newtek.com) infoNOW 115
ReelMotion, Motional Realms (www.reelmotion.com) infoNOW 116

3D at the Speed of Creativity



Chris Meyers, Cybermotion, Courtesy NBC ©1999

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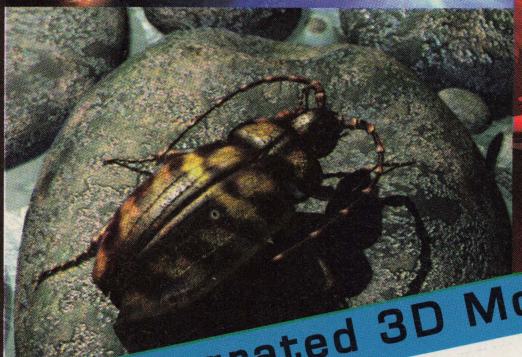

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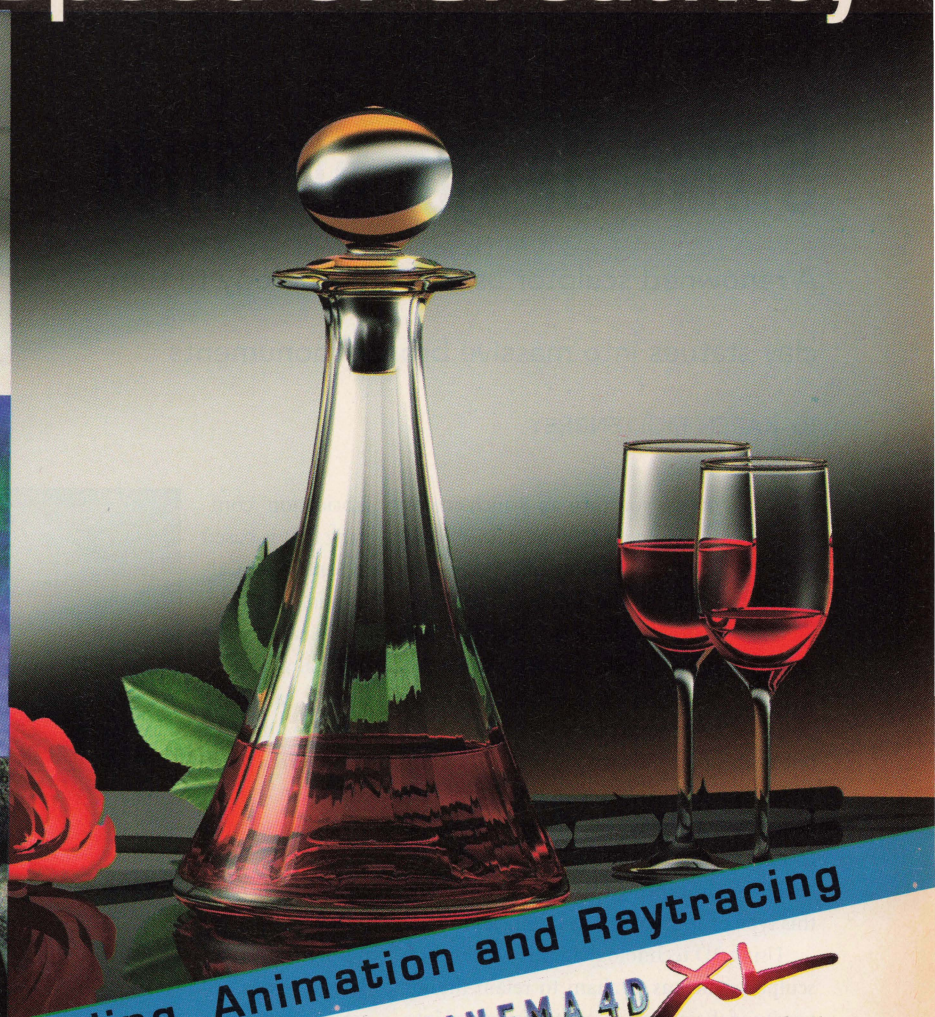

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A renowned sculptor uses 3D technology to turn clay statues into massive bronze monuments

BY KAREN MOLTENBREY

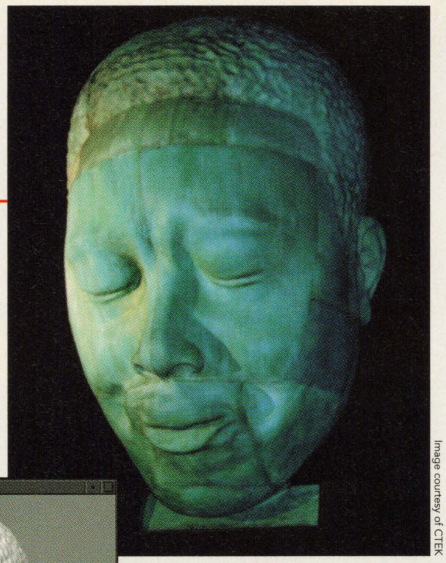


Image courtesy of CTEK

Through digital scanning and rapid prototyping, a small statue of jazz-great Charlie Parker was transformed into artwork of monumental proportions.

How do you turn an 8-inch sculpture into an 18-foot statue? Most sculptors would create the artwork in the intended size, but sculptor Robert Graham has found a different way: using 3D scanning technology coupled with rapid prototyping. "Robert is one of the few artists who uses 3D scanning, which is fairly new to sculpting," says Lisa Federici, cofounder of Scansite, a digital cloning service in San Anselmo, California. "While many other artists feel threatened by this type of technology, he embraces it."

Using 3D technology in this way enables sculptors such as Graham to retain the integrity of their work as it is transformed into larger-than-life proportions. "Scanning provides you with a digital clone—an exact duplicate at almost any size," Federici says. Therefore, digital scanning enables the artist to sculpt a clay piece at a smaller, more manageable size, then output an identical piece at virtually any size.

Graham has been using this methodology for the past few years on projects such as the Duke Ellington Memorial in New York's Central Park and the FDR Memorial in Washington, DC, Federici says. Among the artist's latest accomplishments is the Charlie Parker Memorial in Kansas City, Missouri—an 18-foot bronze statue consisting of a 9-foot base on top of which sits a 9-foot head of the famous jazz musician with his lips pursed, as if playing his trademark saxophone.

The project, however, began with humbler beginnings. When Graham originally completed the sculpture in clay, it was only eight inches high. Sizing up the project was then left to Scansite and CTEK, a design and fabrication company that is based in Santa Ana, California.

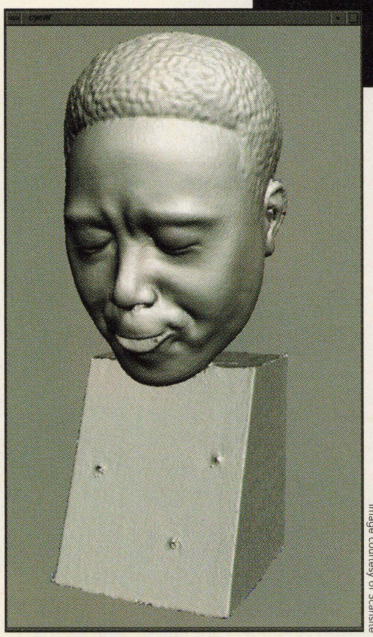


Image courtesy of Scansite

To capture the original geometry of the artwork, Scansite used a Cyberware (Monterey, CA) M-15 3D laser scanner to perform dozens of high-resolution scans at numerous angles. These rings of scans were then merged into a single, large data file using the scanner's CyEdit software running on an SGI (Mountain View, CA) Indigo workstation.

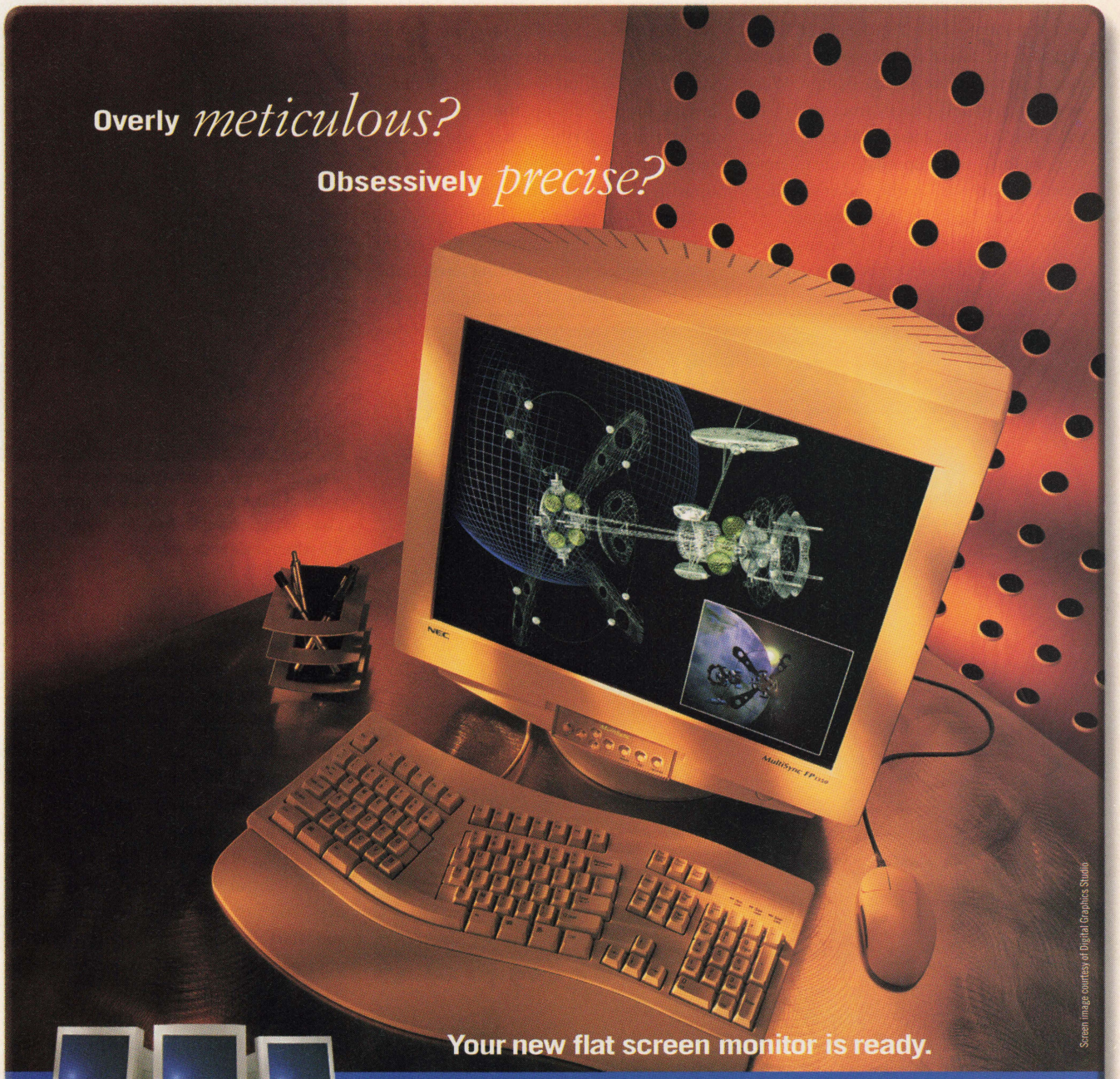
When viewed on the computer, the point cloud of scan data appeared as a 3D image of the object, but in actuality, the image comprised thousands of numbers, each representing an X, Y, and Z coordinate. "Crunching" all those numbers to achieve the single image required tremendous computing power, which was provided by an SGI Octane serving as the workstation's hub.

However, before the data file could be sent to CTEK for 3D output, the team at Scansite still had to translate the 60MB file into STL format used by the CNC milling machine—a process that can almost double the size of the scan file—making it impossible for the millers to work with it in real time. Therefore, before the translation is done, Scansite typically shrinks the scan file by using smart-decimation software shipped with the scanner. The program automatically reduces polygons in areas where a high count is not required to describe the surface geometry, such as along a flat plane. In essence, this makes certain areas of a high-resolution scan low resolution.

For this project, Graham was concerned about losing fine detailing in the top portion of his sculpture, particularly around the head and face of the musician, says Federici. So Scansite went back to the "scanning" board, performing high-resolution scans on the top portion (bust) of the statue and low-resolution passes on the bottom (base), which contained fewer details and deformations. The problem, however, was combining those two data files from different scanners into one, which was achieved with proprietary software written by Scansite.

"To maintain the integrity of the piece, we had to match up those files exactly. We couldn't have the head tilted ever so slightly, and there couldn't be too much or too little space between the head and base," says Federici. "But this helped keep the file down to about 32MB."

Once CTEK received the STL file, the operators attempted to output the sculpture from the rapid-prototyping machine but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soon realized that increasing the scale by such a large amount—from 8 inches to 18 feet—stretched the facets on the surface data so much that the surface became bumpy. "When we did this, milling directly from an STL file was a new concept, and no one realized that you couldn't scale up that much," notes Federici. "This was Charlie Parker's head, so we needed an especially smooth surface."

To rectify this issue, CTEK vice president Javier Valdivieso created a NURBS surface over the scan file's surface using Imageware's (Ann Arbor, MI) Surfacer running on an SGI O2 to create tighter geometry. "When you look at a point cloud, it's a zillion little points. When a laser scanner scales up, those points open up and move farther apart, and the distance between them enlarges, so you end up with a lower resolution," he says. "So we converted the point cloud into a NURBS surface model, then enlarged that to the size we needed without losing resolution."

Although using 3D scanning and printing produces an exact replica of an object, it is not 100% foolproof. According to Federici, having the best scan file possible is crucial to the process. This means there cannot be any noise, or stray data points, because as the file is moved along in the process, through translation and onto milling, "that tiny something gets magnified throughout each step. Then, when it is milled, you say, 'What is that?'

"You have to know the color and reflectivity of the object and if there is any competing light in the room," Federici continues. "You just can't plop down the object and start scanning. You want absolutely nothing interfering with the laser." She recalls a situation in which a group of Scansite technicians were scanning in the dark, and they couldn't figure out why a mysterious spike kept appearing in their CG model. "As it turned out, my small desk light from across the room reflected at just the right angle to cause the problem."

Even if the scan is totally accurate, an artist may decide to make changes once the sculpture is produced at the final scale. But the amount of post-processing work required using 3D technology is little, if any. And this, notes Federici, is where substantial savings in time—and money—are usually made.

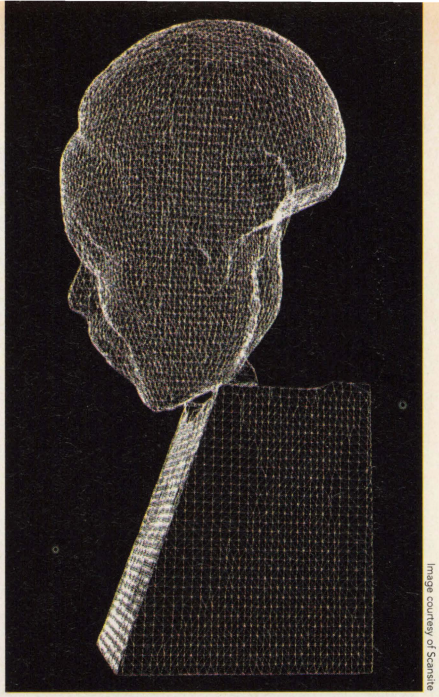

Image courtesy of Scansite

To reduce the digital file size, Scansite created a high-resolution scan of the head portion of the sculpture and a low-resolution scan of the base, then merged the files with software code written in-house.

Key Tool **Cyberware Model 15 scanner**; Cyberware; www.cyberware.com

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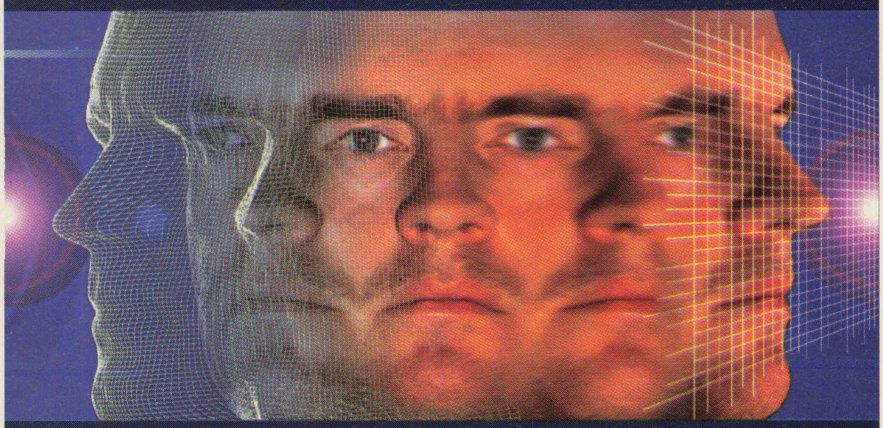

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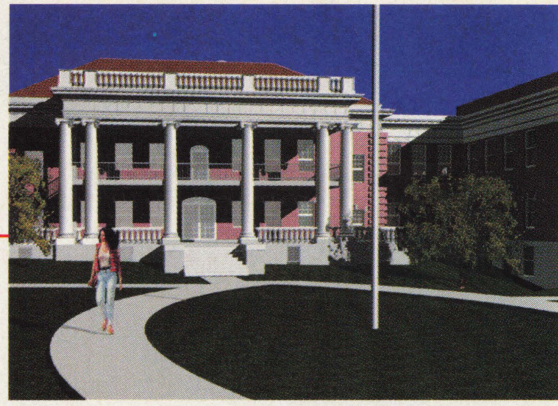
ARCHITECTURE

LEAVING A LEGACY

Laying the virtual groundwork for a community project

BY KAREN MOLTENBREY

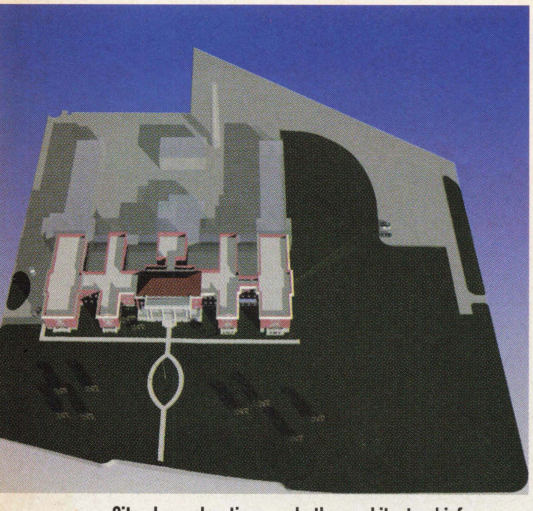


The 3D ArchiCAD model of the proposed Parkland medical facility serves as the centerpiece for the hospital's $25 million fundraising efforts.

When the Dallas chapter of the American Institute of Architects (AIA) was chosen to host the group's 1999 national convention, it wanted to leave a lasting impression on not only the show-goers but the community as well. Following in the footsteps of some previous host-city chapters, the Dallas group provided architectural support to get the ball rolling on a local community outreach project—a redesigned medical-education facility for local residents.

"We wanted a project that we could get off the ground, without assuming the traditional architect's role of design," says Walter Kilroy, a Dallas member of the AIA, who coordinated the effort. "So we provided all the predesign work—feasibility studies, code research, parking planning, landscape planning, conceptual designs, and an exterior building-envelope evaluation."

A large and diversified AIA team provided the fruits of that labor, but the centerpiece—a virtual model of the building's exterior—was created by the Dallas ArchiCAD User Group (DAUG).



Site plans, elevations, and other architectural information can be extracted directly from the ArchiCAD model.

Using the project as a tool to learn Graphisoft's (Budapest, Hungary) ArchiCAD 6.0, the user group set up a virtual office at the Dallas AIA's headquarters, working weekends and evenings to complete the 3D model, renderings, and VR tour of the previously outgrown, abandoned brick building. According to plan, the landmark Parkland Hospital Woodlawn Building will be transformed into the Health Service Center for Dallas, a progressive medical facility.

The most difficult part of creating the 3D model resulted from the structure's unique history. Because the original four-story building was constructed almost 90 years ago, some of the plans and building information was incomplete or nonexistent. Also, several major additions were placed onto the original structure over the years, as its usage evolved. "There are about six or eight buildings all linked together," says DAUG member Steve Williams. This resulted in a confusing set of overall plans for the 180,000-sq.-ft. facility that the group had to replicate in 3D.

So before the ArchiCAD group could begin the modeling process, some volunteers had to measure the perimeter of the abandoned structure to verify some of the original architectural data from the early 1900s. "There was a lot of data that was missing in terms of drawings, so we had to go out to the site, measure, and basically re-create this building," Williams says.

On the front end, the ArchiCAD model serves as a key component of Parkland's $25 million fundraising effort for the new facility, which was the original intent of the 3D imagery. However, on the back end, the model has produced site plans, floor plans, sections, and elevations from which further studies can be done. "When you work in ArchiCAD, you're basically creating the whole building with the computer in 3D, and from that, you automatically get your construction drawings," says Williams.

"The model also serves as an archival record of the additions and changes to the facility, and as a point of origin for the design work to come," Williams continues. Just by modeling the building and providing some presentation and marketing materials, we can extract all kinds of information, he adds.

An additional bonus to the ArchiCAD 3D model is that the information can be saved in various formats—such as DWG and DXF (Autodesk standards), SVF (for the Web), and DGN (Bentley's Microstation). Originally, the AIA chapter had envisioned a totally digital project that would be shared among different CAD platforms by volunteers producing various design schemes, and then later by the architectural and construction firms awarded the contract. So ArchiCAD's platform-sharing ability will enable volunteers to work more proficiently in the software program they are most comfortable with, and the hardware of their choice.

The Parkland plan was one of 24 proposals submitted by community organizations during the search for a Legacy Project, a term coined by the AIA for the community-action programs through which the chapter in the annual convention's host city leaves behind "an architectural residual of lasting value."

Key Tool **ArchiCAD**, Graphisoft (www.graphisoft.com) infoNOW 118

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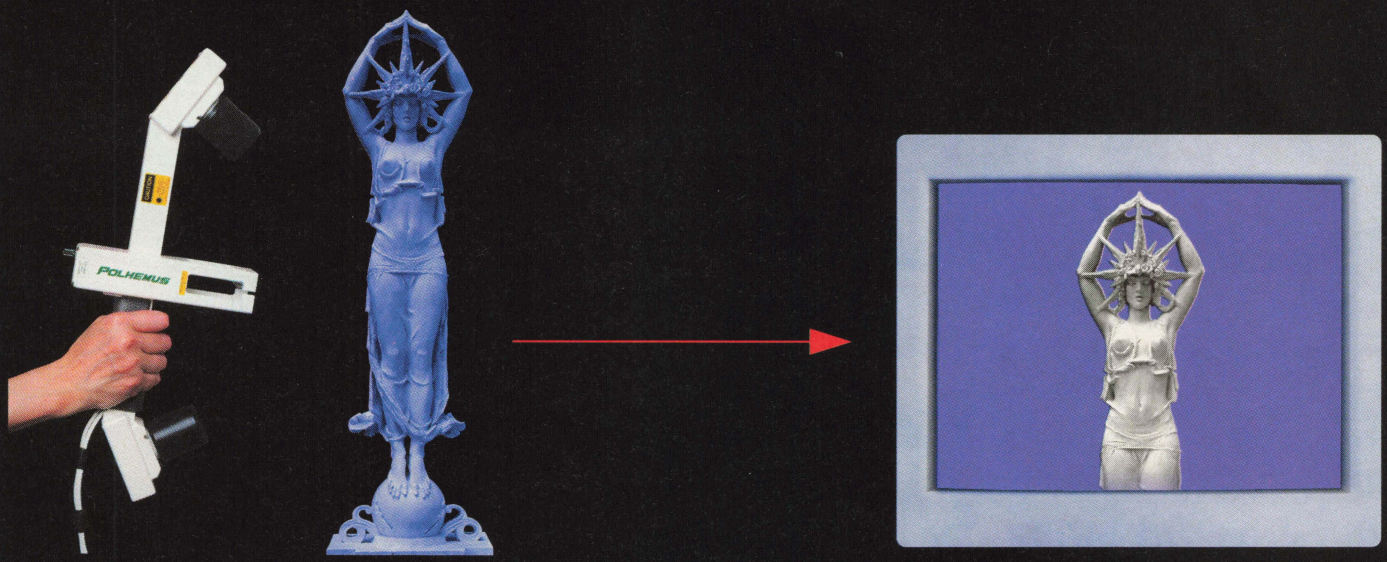

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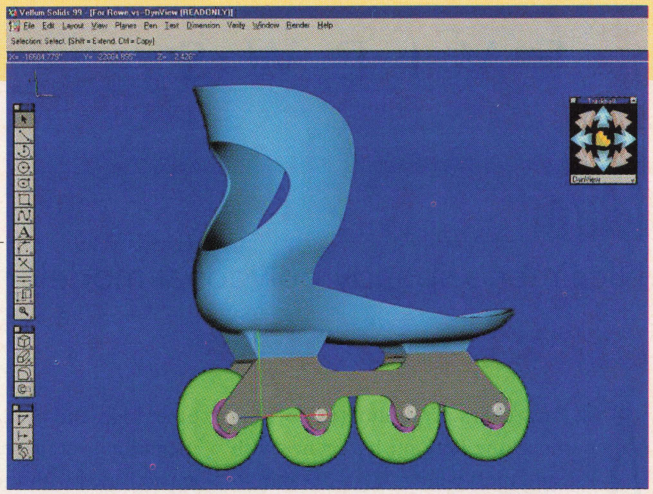
Vellum Solids 99

Ashlar's tool for stylized design

BY JEFFREY ROWE



Vellum Solids 99 is a hybrid modeler that integrates three distinct modeling techniques—surface stitching, feature-based modeling, and local face modeling.

Ashlar's Vellum product line has long been popular with industrial designers, more creative types of designers, and nontraditional CAD users. Now, the company is specifically targeting these groups with Vellum Solids 99. Ashlar has even coined a term for the niche: stylized design. Also setting Vellum Solids 99 apart from the crowd is that it is one of an ever-dwindling number of true CAD products that runs on both Windows and Macintosh platforms.

I reviewed Vellum Solids 99 on an Intergraph TDZ 2000 GX1 with a Wildcat graphics card and found that it performed extremely well, even when rendering complex, organic assemblies. While wireframes are the foundation for sketching and building surfaces and solids in Vellum Solids 99, the software integrates three distinct modeling techniques—stitching, feature-based modeling, and local face modeling.

Stitching combines surfaces into solids. After using the software's wireframe- and surface-modeling tools to define complex free-form shapes, you can use a variety of surface trimming functions to re-limit surfaces and form closed shapes. Supported file formats for sharing data with CAM, CAE, and other CAD packages include IGES (AutoCAD, SolidWorks, Pro/Engineer, and Alias varieties); SAT22; DWG/DXF; Vellum 3.0; VRML (export only); EPS (export only); PICT/BMP; STL; and Adobe Illustrator.

With the software's feature-based modeling, you can create shapes by adding and removing material from a base solid. Vellum Solids 99 provides a variety of methods to create base solids, including primitives, extrusions, sweeps, lathed profiles, and stitched solids.

Finally, Vellum Solids 99's hybrid modeling includes local face operations that let you work independently of how a part is constructed. For example, you can locally modify a face by moving, offsetting, and applying draft angles. Hybrid modeling depends on intelligent object relationships that act as the glue between the three modeling components. Vellum Solids builds these relationships transparently while maintaining both parent/child and history-based relationships, and graphically displays these relationships in the Design Explorer.

Using Design Explorer, you can visualize the relationships between various objects. And unlike a feature tree, the Design Explorer lets you visualize virtually all relationships between wireframe curves, surfaces, and solids.

As do many other mid-range CAD packages, Vellum Solids 99 employs the ACIS 5.X modeling kernel, but Ashlar's software developers have exploited its capabilities more than most, especially the Laws found in ACIS. These Laws are mathematical functions that can power ACIS parameters or geometric formulas for solving especially demanding or unusual geometric problems.

With a new top management team onboard, Ashlar has filled in some holes in Vellum Solids 99 during a relatively short time. For instance, the software finally incorporates online help, and also comes with good supplemental hard-copy documentation. It now supports a redo capability, as well as unlimited undo. Although the file structure in Vellum Solids 99 has changed, Ashlar has accommodated users of previous versions of the product and potential model data incompatibilities with a new export tool option.

Vellum Solids 99 also has new associative drawing composition capabilities—most notably, a model-to-sheet tool. This is a useful feature for efficiently creating simple 2D drawings from solid parts or assemblies. Although the software does not have integrated sheet metal-specific capabilities (this year's "must have"), few conceptual designers require the ability to stamp and form sheet metal.

While some of its competitors are just now moving in this direction, Ashlar continues to develop 2D and 3D software products that let designers concentrate on the creative process, and not so much on the tools. Because Vellum Solids 99 integrates wireframes, surfaces, and solids into one package and continues to be one of the easiest design packages to learn, I'd consider it well suited for designers or even nontraditional CAD users contemplating or actually transitioning from 2D to 3D modeling.

Vellum Solids 99

PRICE: $3995

MINIMUM SYSTEM REQUIREMENTS: Windows 95/98/NT: 233MHz Pentium; 128MB of RAM; graphics accelerator card with at least 8MB of video RAM and OpenGL support Mac OS 8: 604E Power Macintosh; 128MB of RAM; graphics accelerator card with at least 8MB of video RAM and QuickDraw 3D support; ADB port (or USB to ADB converter)

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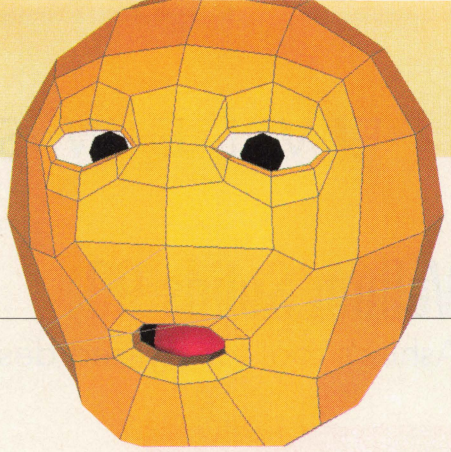
Jeffrey Rowe is the principal of Cairowest Digital Syndicate, an independent multimedia production and technical communications consulting firm. He can be reached at jrowe@cairowest.com.

Mirai

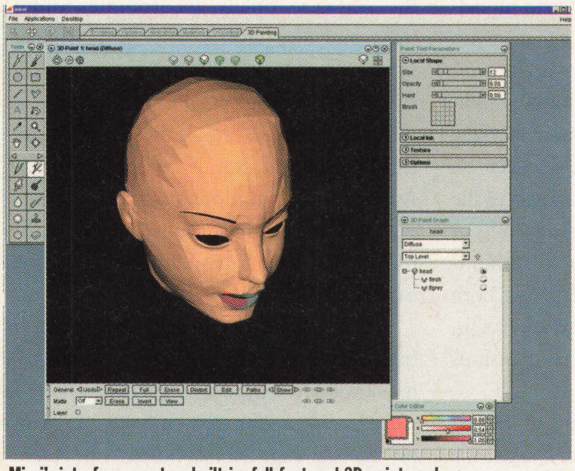
Nichimen's speedy polygonal modeler

BY GEORGE MAESTRI



Mirai's animation tools allow for skeletal and shape animation and include a nonlinear motion editor.

Ask any character animator for the number one item on his or her wish list, and most will say it is a 3D animation package that enables users to manipulate complex models of characters as quickly as possible—preferably at the speed of thought. Nichimen Graphics has come close to fulfilling that desire with its release of Mirai.



Mirai's interface sports a built-in, full-featured 3D paint package.

Mirai is a direct descendant of Nichimen's N-World 3D polygonal modeling, painting, animation, and rendering package. While other software vendors were chasing NURBS, Nichimen ignored the hype and concentrated on refining the polygonal modeler in N-World. Now, with industry favor switching back to polygons and subdivision surfaces, Nichimen is in the catbird seat with the best polygonal modeler on the market.

Mirai is easy to load. You'll notice right away that the interface doesn't contain the fancy icons and floating palettes many other high-end packages sport. Most of the menu items are labeled in simple text, and are activated with the right-mouse button.

A few things about the interface are counter intuitive. For example, objects are invisible when you first create or load them into a scene, so you must manually make them visible.

Modeling with Mirai is intuitive—much like modeling with clay. The package offers one of the most complete tool sets available, with functions for extruding, dividing, and beveling faces and edges. Manipulating models is easy with Mirai's sophisticated magnet operations. The software has a good smoothing algorithm, which you can use to turn a low-resolution model into a high-resolution one.

Once you've modeled your object, you can texture it using a standard array of shaders, or the software's built-in 3D paint module. This module is one of the nicest I've seen. It's a core feature of the package that allows you to animate brush strokes within a texture map and layer textures to obtain rich effects. Absent from the module, however, is support for procedural textures.

Deforming surfaces in Mirai is easy and can be accomplished by animating skeletons (the usual way) or by animating shapes. For shape animation, the software operates around the concept of states. A state is a shape, such as a facial animation target. The shape can be either absolute or relative to a base shape, such as a neutral face.

Skinning a character to a skeleton is also a simple process accomplished through a few menu clicks. Once the skin is attached to the model, you can manipulate it by moving the skeleton. I really like the way Mirai's skeletons work. The system is unique in that you can manipulate each joint via inverse kinematics (IK) or forward kinematics at any time.

Once you get down to animating, Mirai is a breeze. Keyframing and editing can take place at a number of levels. For example, you can keyframe a skeleton as an object rather than as a collection of joints, which makes it much easier to change positions globally. For those who like to have control over individual joints, Mirai also enables manipulation of the individual curves for each joint.

The software is also is good at handling motion-capture data and is a sophisticated motion editor. You can move, stretch, squeeze, and layer animation and motion-capture data to your heart's content. Mirai is used extensively in the gaming community, so import and export of animation data for all the major game engines are supported.

Furthermore, the software includes a number of workflow enhancements, such as the ability to reference master files so multiple users can work on a scene simultaneously.

All in all, Mirai is an excellent package for those who animate characters on a regular basis. As increasing numbers of animators begin to embrace tools such as subdivision surfaces and nonlinear motion editing, packages such as Mirai will start to take center stage.

George Maestri is a Los Angeles-based writer, director, and producer.

Mirai

PRICE: $6495

MINIMUM SYSTEM REQUIREMENTS:
Windows NT: 266MHz Pentium II; 128MB of RAM; 300MB of hard-disk space; 300MB of virtual memory; qualified OpenGL accelerator; three-button mouse
SGI: Irix 6.3 and above; 128MB of RAM; 300MB of hard-disk space; 300MB of virtual memory

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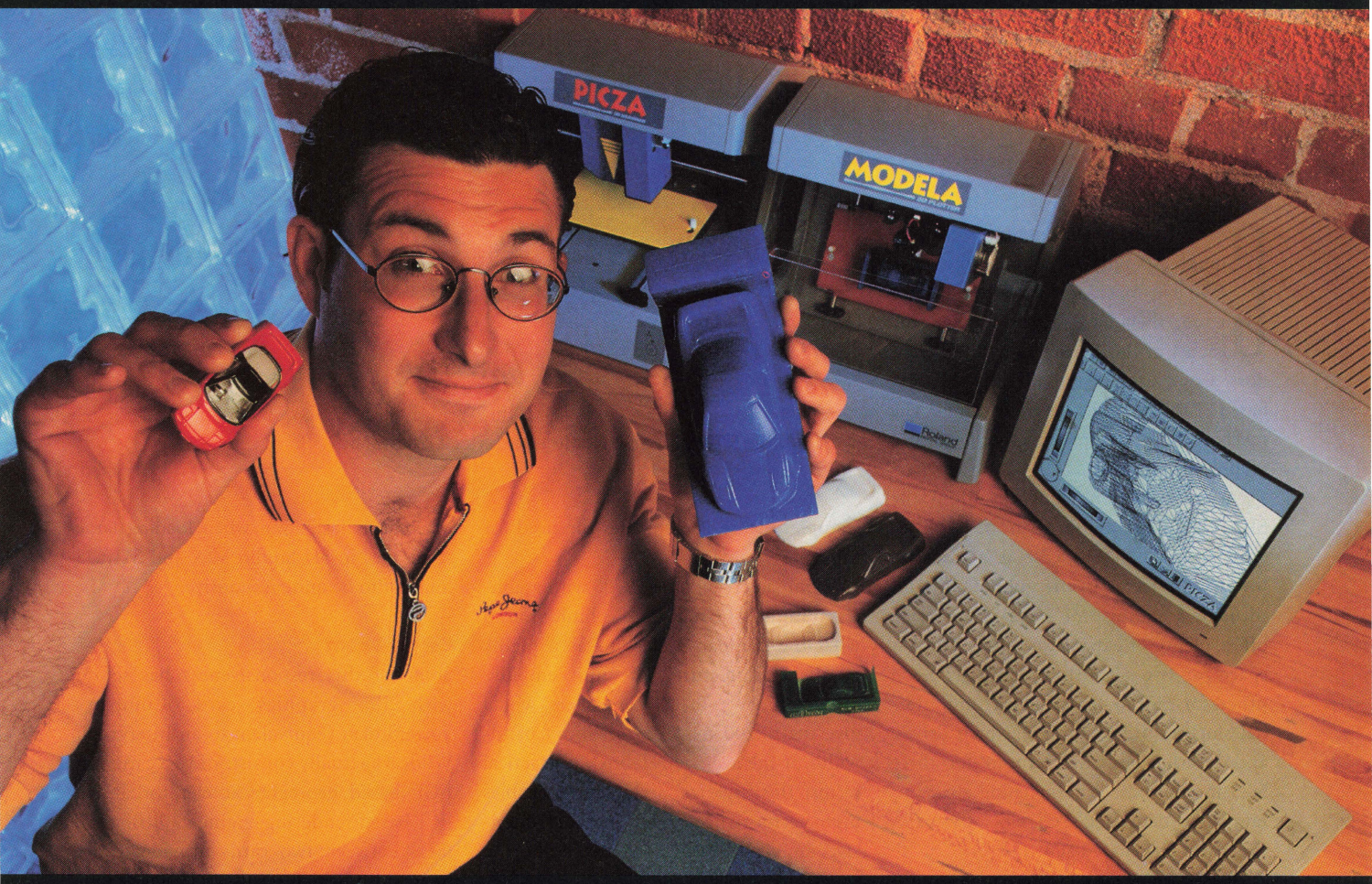

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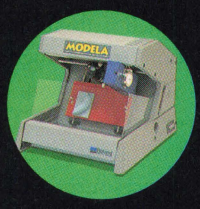

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SP700

Compaq's NT graphics workhorse

BY GEORGE MAESTRI

The SP700 offers ample room for expansion inside its tower case.

Compaq has been pursuing the 3D graphics arena for some time now. While its machines have typically been good, they have never attained the cachet of those from some other vendors. Compaq's newest offering, the NT-based SP700, may change a few minds. The machine is built from the ground up as a graphics workhorse.

As are most Compaq workstations, the SP700 is solidly built in terms of its physical components. The case is a mid-size tower with access to the guts of the unit through a sliding side panel. The inside offers plenty of expansion room: There is space for two 500MHz or 550MHz Xeon processors, up to 4GB of RAM, and internal slots for up to three 3.5-inch drives, and external slots with room for three 5.25-inch devices. The machine also contains five dedicated PCI slots, two ISA slots, and one shared slot.

Rather than being situated on the motherboard, these slots are on a pull-out card cage. To install a third-party expansion card, you must pull the cage out of the unit, install the cards, then reinstall the cage into the workstation. Removing and reinstalling this cage can be tricky, so if you have a lot of expansion cards, prepare yourself for some frustration.

In addition to the PCI slots, the machine also has a single AGP slot, which connects directly to the motherboard. On the back of the SP700 are plenty of ways to connect to the outside world. In addition to the requisite serial, parallel, and joystick ports, the machine also sports two USB ports, Ethernet, an ultrawide SCSI port, and two IEEE 1394 ports for DV in/out. It's nice to see DV included as a standard feature, because it eliminates the need for third-party cards.

Compaq created the SP700 with graphics in mind: The hardware is built around what the company refers to as a highly parallel architecture. The unit employs dual-memory and PCI controllers, which give the SP700 twice the memory bandwidth of the average NT box. In practical terms, this style of architecture enables high performance under memory-intensive applications such as 3D authoring programs.

The configuration also provides the unit with twice the usual PCI bandwidth, which is useful for bus-intensive applications such as digital video. A dual-channel SCSI lets you place high-bandwidth devices such as hard disks on a channel that is separate from low-bandwidth devices such as CD-ROMs.

The best test for any machine is a real-world application. With this in mind, I evaluated the SP700 against a variety of packages, including Softimage, Maya, and 3D Studio Max. All the software worked well, and there were no discernable problems with the OpenGL drivers. The PowerStorm 600 graphics adapter included with my review unit has a good history of OpenGL support. In a nutshell, the machine is fast. Even when loading large scene files in 3D Studio Max and Maya, I found it to be quite responsive.

SP700

PRICE: $7377 (as configured below)

CONFIGURATION:
Two 550MHz Xeon processors; 256MB of RAM; 9.1GB hard disk; Windows NT 4.0

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Cards Count

Some of this responsiveness has to do with the graphics card. Compaq's PowerStorm (equivalent to an Intergraph Wildcat) actually consists of two cards: an AGP based geometry accelerator and a PCI-based rendering engine. Splitting the tasks between two cards provides more bandwidth, which results in better graphics performance. The card is certainly one of the fastest on the market. Texture memory is a healthy 64MB, which should satisfy most applications.

And for those with smaller performance requirements, Compaq offers three less-expensive graphics cards: the PowerStorm 300, an Elsa Gloria XL, and a Matrox Millennium.

As for price, the machine is definitely on the high end of the scale, due in part to the graphics card and the high-end Xeon processors. The quality of the construction also figures into the equation.

The SP700 is a solid machine with a unique architecture that lends itself to graphics applications. While the price is a bit high, the machine is certainly a durable workhorse and will do quite well in most high-end production situations.

George Maestri is a Los Angeles-based writer, director, and producer.

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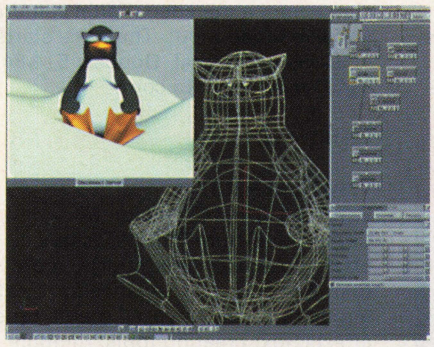
UNIX The procedural technology found in Houdini 3.0 from Side Effects Software takes realtime/interactive



animation to the next level. This version offers an enhanced version of Pixar's subdivision surfaces, rational curve networks, and radial fillets. Other features include advanced hidden line wire rendering (WREN) and IGES file format support. The company also plans to port Houdini to the Linux O/S. The price is $17,000. (Toronto, ON; 416-504-9876; www.sidefx.com)
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NURBS MODELING

WIN A number of industrial design-oriented features and enhancements have been incorporated into solidThinking 3.5 from Gestel. These include C2 continuity surfaces, advanced polygonal modeling with support of n-side polygons, full support for interactive subdivision surfaces adhering to Pixar implementation, and high-performance redrawing with complex scenes, both in wireframe and shaded visualization mode. The surface tangency align modeling tool enables users to align a surface border to any other surface trim edge, with the ability to specify the incident angle between the two surfaces. The price is $1495. (Vicenza, Italy; +39 0444 99 11 00; www.gestel.com)
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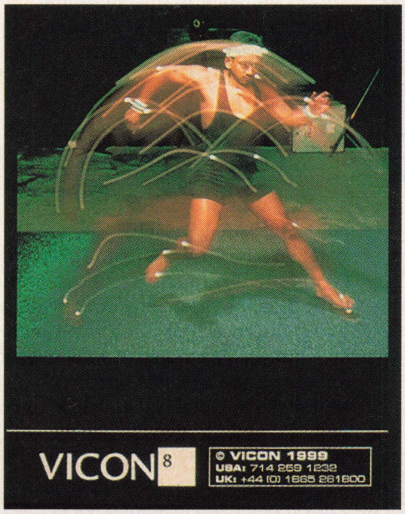
MOTION CAPTURE

WIN Providing production-strength optical motion capture, Vicon 8 from



Vicon delivers high-quality motion through hardware, software, and support. Using this product, there are four stages to motion capture: calibrate, capture, pipeline, and post-process. The system can use 24 cameras to capture multiple actors interacting in the performance area. The software enables users to capture all the subtle ways people interact. Additionally, the system can capture any duration up to 24 hours, offers full SMPTE timecode support, and can capture either full body movement or face movement. The price is not available. (Tustin, CA; 310-450-1482; www.vicon.com)
Booth 1939
infoNOW 129

FILLETS AND BLENDS

WIN The latest release of SMLib from Solid Modeling Solutions offers capabilities for multi-surface fillets and extensive blending functionality. The company has implemented a framework that handles the basic topological cases and includes a useful set of geometric cases. The framework is designed to handle most of the bookkeeping tasks and includes an object-oriented difficult condition handler. The end user can change the default behavior by implementing a subclass of the particular handler. The product is licensed for $2000/month for internal use at one site or $2500/month for external use of the resultant applications with no royalty charges. (Bellevue, WA; 425-746-5479; www.smlib.com)
Booth 2361
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LIGHTWAVE ENHANCED

WIN LightWave 6 from NewTek offers a massive new suite of tools and technologies, including Intellegentities, Endomorphs, Skelegons, MicroMesh, interactive subdivision surface modeling, 96-bit floating point render pipeline with caustics, HyperVoxels, and distributive ray tracing. The price is less than $3000. Also, version 2 of Aura, the professional video paint, layering, and compositing tool, adds a high-resolution video paint engine, a chroma keyer with blue spill technology, and a keyframer with built-in motion tracking. The software has video stencils, gradients, and textures that require no rendering time. The price is less than $1000. (San Antonio, TX; 210-370-8000; www.newtek.com)
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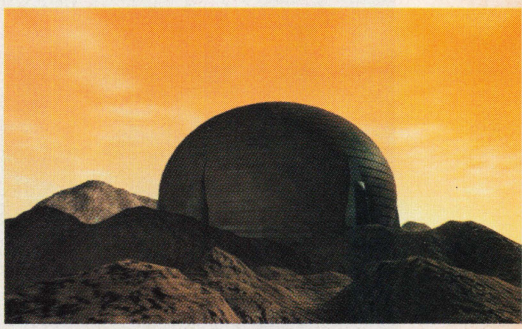
PARTICLE SYSTEM

WIN MatterWaves 1.0 from Trinity Animation is a flexible and completely independent material-mapped particle system for 3D Studio Max. Capabilities of the plug-in include emission of Matterwaves particles



from any Max particle system, map and gradient-based object fragmentation, interparticle dynamics, light-driven particle emission, map-based particle parameters, and metaparticles for blobby effects using MatterWaves features. The price is $295. (Lee's Summit, MO; 816-525-0103; www.trinity3d.com)
Booth 2303
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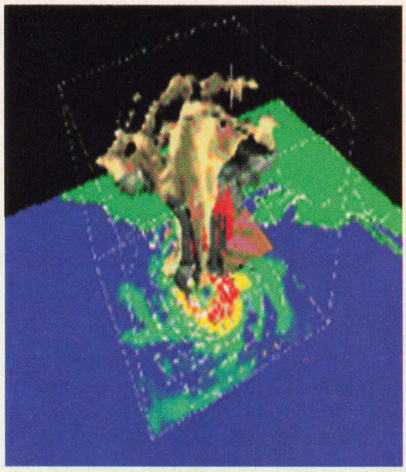
ADVANCED VISUALIZATION

WIN/UNIX Release 4.0 of IRIS Explorer from Numerical Algorithms Group offers collaborative visualization,



which enables geographically separate users to share data, map construction, and control modules. Other new features include improved facilities for plotting graphs of y against x, improved printing facilities, and an improved drawing area widget. New modules include LineGraph, Layout, and DecimateGeom. The price is not available. (Downers Grove, IL; 630-971-2337; www.nag.co.uk)

Booth 229

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2D SATELLITES

WIN The launch of four CTP Satellites-paint, scan, render, and pencil-test-coincides with the release of CTP Version 1.3 2D animation software from Crater Software. According to the company, the total production program is intended for both individual freelancers and small- to medium-size studios and production companies. The price is not available. (Montreal, Quebec; 514-284-7771; www.cratersoftware.com)

Booth 719

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MULTIMEDIA/VIDEO

NONLINEAR EDITING

WIN The RT2000 from Matrox Video Products Group is a realtime nonlinear editing system for corporate and event video artists. The product's architecture exploits the 3D graphics performance of the Matrox Millennium G400 accelerator to provide broadcast-quality 3D DVE and 32-bit uncompressed animated graphics in a native DV editing environment. Realtime MPEG-2 output for DVD, video CD, and Web video-streaming applications, along with 1394 and analog video output for tape round out the product. The bundle includes the Millennium G400 graphics accelerator, the RT2000 codec card, an audio/video breakout box, and a content creation suite that includes Adobe Premiere RT realtime nonlinear editing software, a professional titler, and an audio editor. The price is $1295. (Dorval, Quebec; 514-685-2630; www.matrox.com/video)

Booth 1135

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ON-LINE PRODUCTION

WIN/UNIX Available in the 2.0 version of Filmbox from Kaydara are tools for improving on-line production, including Camera Reality and Video Reality 2.0. The tools enable users to work fully in context for real-time production, seamlessly integrating digital characters, a matched digital camera, and live video input. The price starts at $4995. (Montreal, Quebec; 514-842-8446; www.kaydara.com)

Booth 2411

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VISUAL EFFECTS

WIN/MAC The NT version of Commotion from Puffin Designs offers dozens of filter effects, more than 200 preset FX brushes for creating textured and stylized media brush effects, text creation tools, multiple undo, and support for third-party filter plug-ins. Two plug-in packages for Adobe After Effects include

Composite Wizard ($695) and Image Lounge ($695). The company also offers Primatte Keyer ($695) for creating chromakey mattes within Adobe After Effects. (Sausalito, CA; 310-450-1482; www.puffindesigns.com)

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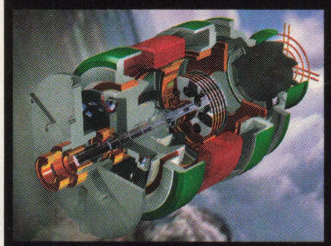

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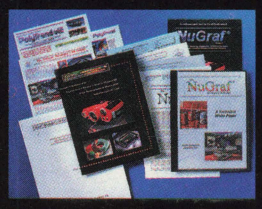

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RexRack	Rack-Mount DV Editing Workstation	$6995
PINNACLE SYSTEMS miroVIDEO DV300	FireWire I/O card w/built-in Adaptec SCSI Controller	$679
miroVIDEO DC30PRO	A/V Capture card w/Adobe Premiere 5.1 and Adobe	$830
miroVIDEO DC50	A/V Capture card w/Adobe Premiere w/component I/O	$1720
DPS DPS RT	DPS Perception RT3DX NTSC only with SDI I/O Option	$9499
PVR 2500	Perception Video Capture Board NTSC only	$1579
FAST The Art of Digital Video. AV Master Plus	PCI Video Capture with MediaStudio PRO 5	$599
DV Master Pro	FireWire with speed razor DV Software	$2995

The 3D Shop

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3dfx 3Dfx 3500 AGP	Voodoo 3 16M 183Mhz SGRAM TV/S video out	$225
3Dfx 3000 AGP	Voodoo 3 16M 166Mhz SDRAM,Dual 32-bit,TV	$152
3Dfx 2000	Voodoo 3 16M 143Mhz SDRAM,Dual 32-bit AGP/PCI	$110
Glyder Max II	Permedia II Chipset w/8M PCI/AGP	$66
TX-GOLD 316	TX Chipset 8Mx8M PCI	$135
STB Symmetric VELOCITY 4400	16Mb Twin Texel Processor AGP or PCI , TV Out	$119
BlackMagic 3D	Voodoo2 3DFX Chipset with 12meg PCI	$110
VELOCITY 128	nVIDIA Riva 128ZX AGP, TV Out	$85
Galileo 15	XGA Dual 15" Flat Panel LCD Monitor, NT only	$2995
E&S E&S Tornado3000	62MB Dual Screen, True color 1920X1200, Stereo	$1550
AccelGalaxy	52M E&S Chipset 20Mx32M Dual Screen Ready stereo	$1160
AccelEclipse II 32	Eclipse II Mitsubishi 3DPro/2mp32M AGP/PCI	$955/$799
Accel Lightning	1200 31MB AGP Open GL/ Accel Star II AGP/PCI	$649/$115
3Dlabs Oxygen RPM	64M 2 Oxygen RPM Chip Dual Screen Ready AGP	$720
GMX 2000	Dual Gamma MX Chipset 16Mx80M OpenGL AGP	$1430
Oxygen VX1	32mb 2XAGP R3 Processor&Jetstream Architecture	$229
Oxygen GVX1	32mb of unified SGRAM,framebuffer,Z-buffer	$739
Oxygen ACX	8mb SGRAM AGP/PCI 1600X1200, open GL 1.1	$119
ELSA GLoria Series	XXL GMX1000 AGP/MX 40M PCI/MX 24M PCI	$1350/$1060/$699
GLoria Synergy 8	Permedia II Chipset 8M PCI / AGP Video in/out	$119
ERAZOR III w/v	32MB AGP4X Nvidia Riva TNT2	$220
Synergy II	16MB/32MB AGP4x Open GL TNT2 chipset	$215/$259
Winner II 32MB	3DRT W/glasses 4X AGP 128bit 2D/3D Graphics	$189
matrox Millenium G400	32MB,Dual Head,300MHz 2D/3D DVD	$229
Millenium G400Max	32MB,Dual Head,360MHz 2D/3D DVD	$269
Marvel G-200-TV	Comes with 8meg SGRAM and TV Tuner AGP	$250
Productiva G-100/D	G+DUALP Dual Monitor support (2)4mb 64bits PCI	$450/640TV
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Leadtek Leadtek S320II	S320II/PRO/Ultra Version w/32M TNT2 Chipset	$175 / $189 /$199

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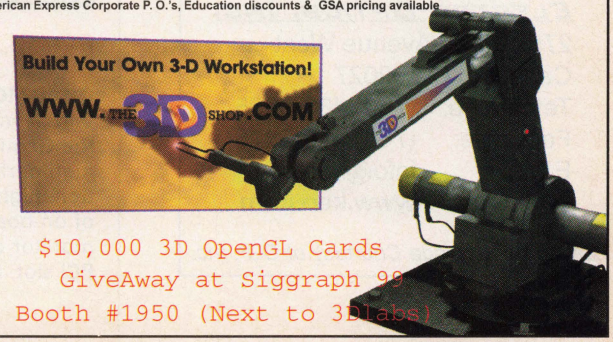

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port program for software developers using the MuSE Development System. Members receive an extensive software toolkit with sample code and manuals; discounts and services to help lower the cost of doing business as a muSE Developer; extensive marketing and technical support; and access to regularly scheduled seminars, tutorials, and an annual (uSE Developers Conference. Membership fees range from $99 for the Basic Developer package to $1000 for the full Professional Developer program. (Albuquerque, NM; 505-843-6873; www.musetech.com)
Booth 1025
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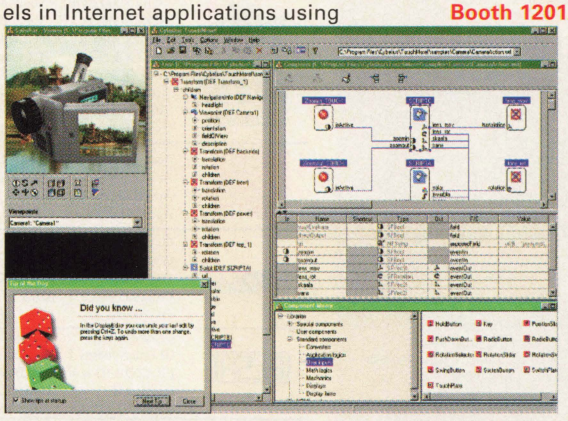
WEB DESIGN

INTERACTIVE 3D

WIN/MAC/UNIX Add interactivity and functionality to 3D VRML product models in Internet applications using



TouchMore! 2.0 from Cybelius Software Inc. This Java-based tool can be used at every stage of a product's lifecycle. New features include an optimizer for reducing VRML file sizes by 50% and a display editor for creating virtual LCD displays for functional 3D product models. The price is $995. The ShowMore! 1.1 product enables users to integrate a 3D VRML model of a product with HTML. The price is $149. (San Jose, CA; 408-971-1800; www.cybelius.com)
Booth 2032
infoNOW 128

HARDWARE

BOARDS

DUAL-MONITOR CARD

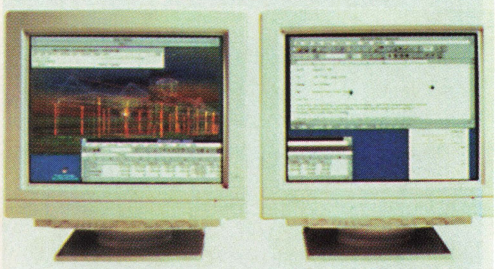
WIN A multiple-monitor graphics card, the Gemini from Appian Graphics offers high-performance 2D and 3D acceleration, high-resolution display, and 16MB of on-board SGRAM. Providing dual-monitor output from a single AGP or PCI slot, the board uses one S3 Savage/MX graphics accelerator. It is equipped with video input and overlay capability as well as the optional Appian TV Tuner, which provides the ability to tune broadcast video, autoscan channels, and deliver stereo sound. The price is not available. (Redmond, WA; 425-882-2020; www.appian.com)
Booth 2335
infoNOW 140

HDTV TECHNOLOGY

UNIX The SGI HD I/O board takes advantage of the high system and I/O bandwidth available on SGI's Onyx2 workstations and Origin servers, enabling them to support multiple streams of realtime, uncompressed HDTV I/O in either 1080I or 720P formats. (Mountain View, CA; 650-933-1961; www.sgi.com)
Booth 1201/1401
infoNOW 142

EXPANDED SPACE

WIN Designed on the premise that the more you see the more you can do, the Jeronimo 2000 from Appian Graphics enables users to maximize space across two displays from a single AGP or PCI slot. With 2D/3D, OpenGL, Direct 3D, and DirectX support, the product is intended for applications involving CAD/CAE, desktop publishing, and digital content creation. Video overlay support enables users to receive real-time video feeds from a baseband source such as a VCR or camcorder. Built with two Permedia 3 chips from 3Dlabs, the product delivers realistic images and scenes with its high-resolu-



tion display, DVD motion compensation, and color space conversion as well as 125 million multi-texture pixels per second fill rate. The price is not available. (Redmond, WA; 425-882-2020; www.appian.com)
Booth 2335
infoNOW 141

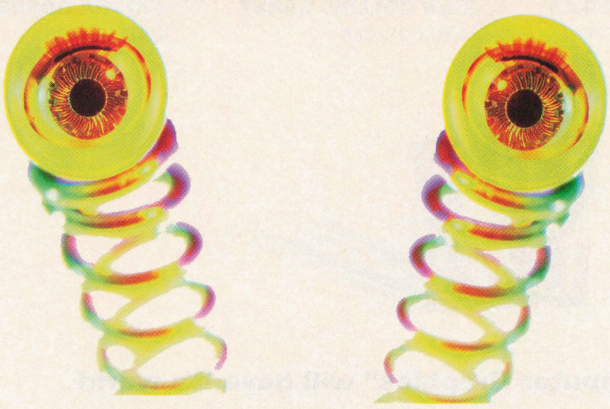


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PHOTO: John Warnock is featured in the film *"The Story of Computer Graphics"*

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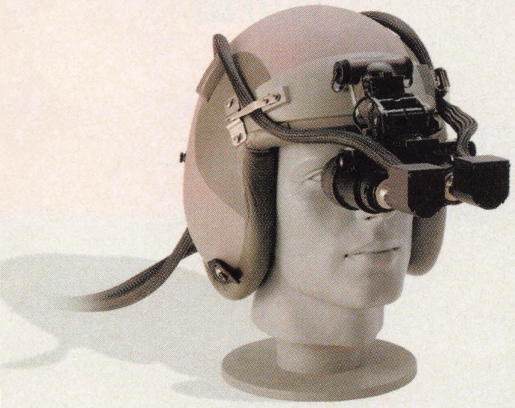
DISPLAYS

IMMERSIVE DISPLAY

WIN/UNIX A versatile, Virtual Model Display (VMD), the Mini WorkBench from Fakespace enables stereoscopic viewing and manipulation of dimensionally accurate, 3D visualizations. It can also be configured with an on-screen-digitizing tablet to support real-time, direct input design in a 2D-viewing mode. This adjustable, drafting table-style rear-projected display system enables real-time viewing and manipulation of computer-generated models. The display measures 44 inches diagonally. Three configurations are available, priced starting at $56,995. (Mountain View, CA; 650-688-1940; www.fakespace.com)
Booth 339
infoNOW 143

ADVANCED VISIONS

WIN/MAC/UNIX New from n-vision, the Datavisor NVG is an immersive display system that simulates night vision goggles (NVGs). The product enables simulation and training appli-



cations that utilize NVGs in real time. It accepts standard 60Hz monochrome or color video to display between 1280x1024 and 1700x1350 pixels per eye, monochrome. The price is $25,000. The company also offers the Datavisor LCD, a wide field-of-view head-mounted display system designed for use in both immersive simulation and augmented reality applications. The price is $10,000. (McLean, VA; 703-506-8808; www.nvis.com)
Booth 925
infoNOW 144

INPUT/OUTPUT

SOLID OBJECT PRINTER

WIN Turn computer images into physical three-dimensional objects using the ThermoJet Solid Object Printer from 3D Systems. The unit produces a sample in a plastic-like material, which offers a real-world example of what may be difficult to comprehend when viewed as a complex CAD image on a computer screen. Because ThermoJet files can be sent over any network, including the Internet, the machine can be used as a 3D fax to send models to other cities or continents for output within hours. The price is $49,995. (Valencia, CA; 888-337-9786; www.3dsystems.com)
Booth 501
infoNOW 147

FILM RECORDER

WIN/MAC/UNIX The CRT-based Solitaire Cine V image recorder from Management Graphics delivers more light, which means faster imaging speeds and greater density on a variety of film formats, including 35mm Cine/Academy, 35mm Vistavision, 65mm, and 4x5. Imaging speeds range from 12 seconds at 2K resolution to 23 seconds at 4K on Kodak color negative 5245 film for the 35mm Cine/Academy formats. Users can image to 5244 intermediate film stock, a capability that benefits special

effects. Electronic controls automatically adjust imaging. The price is not available. (Minneapolis, MN; 612-854-1220; www.mgi.com)
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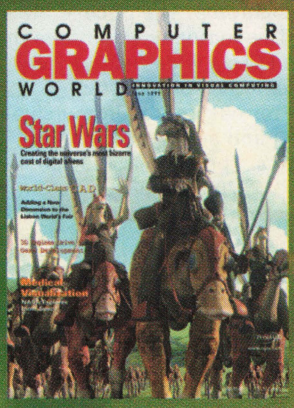

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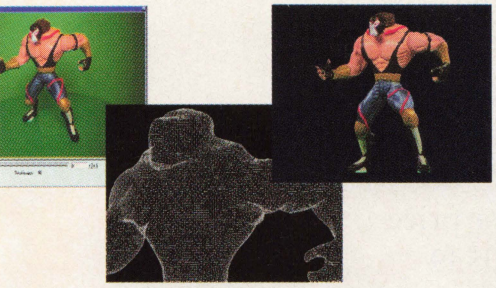
3D OBJECT SCANNER

WIN Generate fully textured 3D models of objects in minutes without stitching, using version 1.0 of 3Scan from Geometrix. The product uses a low-cost

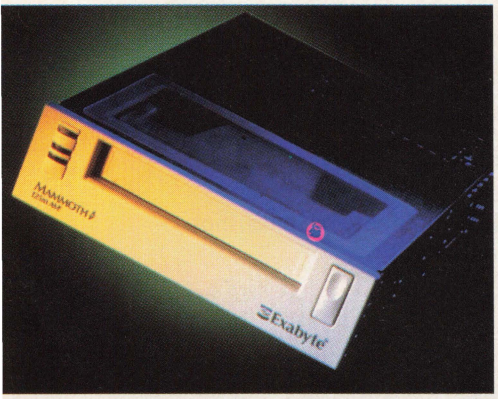


digital camera powered by 3Scan software. The camera takes multiple images of an object as it rotates on a computer-controlled turntable. From these images, the software extracts the complete 3D geometry of the object and creates textures that are UV mapped onto the geometry. The resulting models can be output in various file formats compatible with professional 3D authoring and painting tools. Objects up to 18 inches wide by 13.5 inches tall or as small as a golf ball can be scanned. The price is $7495. (San Jose, CA; 408-999-7498; www.geometrixinc.com)
Booth 937
infoNOW 146

STORAGE

TAPE DRIVE

WIN/MAC/UNIX The Mammoth-LT from Exabyte delivers 14 gigabytes of capacity and 120-megabyte-per-minute throughput and can back up 7.2 gigabytes in an hour. Available in internal or



external Low Voltage Differential and single-ended SCSI configurations, the drive is rugged, reliable, and automation ready. The price is $1895. The 125m AME media costs $58. (Boulder, CO; 800-774-7172; www.exabyte.com)
Booth 2537
infoNOW 148

SCALEABLE STORAGE

WIN/UNIX New from Ciprico, the FibreStore RAID system utilized the FibreStore JBOD disk array with inte-

grated single or dual RAID controllers to deliver scaleable, fault-tolerant storage for visual computing and digital media. The system's high-bandwidth parallel disk access technology is coupled with an on-board cache to deliver continuous, sustainable data rates at close to 200MB per second with the dual controller option. The product supports all the Fibre Channel fabric topologies required by the SAN technologies. Storage capacities range from 144GB to 2TB. The price starts at $70,000. (Plymouth, MN; 612-551-4000; www.ciprico.com)
Booth 529
infoNOW 149

SYSTEMS

CREATIVE POWER

WIN Intergraph Computer Systems offers HD systems that are capable of streaming 1080I or 720P format video or multiple streams of standard definition video. The company also offers new high-performance 3D graphics options for its worksta-

tions. (Huntsville, AL; 800-763-0242; www.intergraph.com)
Booth 547
infoNOW 152

TV PRODUCTION

WIN The Editbox FX from Quantel addresses the growing demands for DTV, 16:9 widescreen, and HD editing. In addition to enhanced ergonomics the 16:9 DTV-ready system gains powerful effects plug-ins, with background processing via the Quantel Open Render Engine. The company also offers a

24fps option. The Clipnet open high-speed multiformat network operates as a background task and enables the fore-

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✔ Relates to computer graphics

✔ Has shipped or will ship in 1999 (no betas)

✔ Represents a significant innovation that expands the boundaries of visual computing—not merely revolutionary improvement or lower price

FAX this form back to us: 603.891.0539

Company name:_____

Mailing address:_____

Phone numbers (toll-free, if applicable, and toll): _____

URL:_____

Product name, including version number:_____

Brief description of product and its target user: _____

_____

_____

Price: _____

How the product demonstrates innovation and how that innovation is unique (indicate what technological barrier the product breaks, what problem it solves, and how that benefits the user):_____

_____

_____

_____

_____

Contact name at company in case of questions: _____

Name and title of company president or CEO:_____

Winners will be announced in the January 2000 issue of *Computer Graphics World.*

Please fill out and fax this nomination form (one per product) to the attention of Michelle Lendway at 603-891-0539 by October 15, 1999.

Forms are also available on our Web site at **www.cgw.com**.

IMPORTANT: When submitting a nomination form, please also send a high-res photo or screenshot of your product to: Michelle Lendway at mlendway@pennwell.com.

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ground operations to continue without interruption. Additionally, the Editbox Chaser allows an existing Editbox to provide genuine nonlinear HD finishing. The price is not available. (Darien, CT; 203-656-3100; www.quantel.com)
Booth 1701
infoNOW 150

ENHANCED WORKSTATIONS

WIN IBM's IntelliStation E Pro and M Pro NT-based workstations feature Intel's 550MHz Pentium III processor. The systems include the FireGL1 and Intense 3Dwildcat 4000 graphic as well as Matrox Millennium G200 and Appian Graphics. Both workstations are equipped with 100MHz ECC SDRAM, with capacities to 768MB for the E Pro and 1GB for the M Pro. Both utilize Intel's 440 BX chip set and AGP 2X. The workstations can be configured with a choice of 7200rpm and 10,000rpm disk drives ranging in capacity from 6.8 to 18.2GB. The price is $2222 for the E Pro and $2576 for the M Pro. (Research Triangle Park, NC; 919-254-7037; www.ibm.com)
Booth 1231
infoNOW 151

VISUAL WORKSTATIONS

WIN/UNIX SGI's family of visual workstations includes the Silicon Graphics 320 and Silicon Graphics 540 systems for Windows NT and the Silicon Graphics O2 and Octane systems for Unix. These systems feature graphics

and digital media capabilities that enable advanced visual computing on the desktop. New O2 and Octane workstations are based on the 270 and 300MHz MIPS R12000 processors. (Mountain View, CA; 650-933-1961; www.sgi.com)
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EVENTS

AUGUST

8-13 · SIGGRAPH, held in Los Angeles. Contact: Smith, Bucklin & Assoc. Inc. (312-644-6610); (fax: 312-321-6878); www.siggraph.org/s99/

17-18 · InternetASP Forum '99, held in San Francisco. Contact: Ambit Interational Inc. (415-392-4200); (fax: 415-392-4205); www.ambitsf.co

21-25 · URISA '99, held in Chicago. Contact: URISA (847-824-6300); (fax: 847-824-6363); www.urisa.org

31-Sept. 3 · Interact + PC IT 99, held in Melbourne, Australia. Contact: Australian Exhibition Services (+61-3-9261-4500); (fax: +61-3-9261-4545); www.ausexhibit.com.au

SEPTEMBER

9-10 · Northwest Computer Show, held in Minneapolis. Contact: AITP (612-894-8007); (fax: 612-894-8252); www.nwcs-mn.com

12-15 · Spectrum '99, held in Tucson, AZ. Contact: GCA (703-519-8160); (fax: 703-548-2867); www.gca.org

13-16 · Computer Technology Solutions held in conjunction with the Detroit Advanced Productivity Expo (APEX), held in Detroit, MI. Contact: SME (313-271-1500); (fax: 313-271-2861); www.sme.org

22-25 · digiMedia 99, held in Dusseldorf, Germany. Contact: Dusseldorf Trade Shows (312-781-5180); (fax: 312-781-5188); www.dtsusa.com/dts/

29- Oct. 1 · Bentley International User Conference, held in Philadelphia. Contact: Bentley (610-458-5000); www.bentley.com/biuc/register

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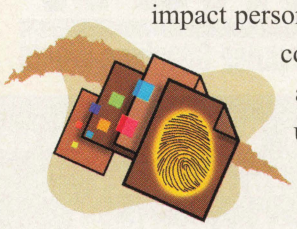
PROFITING FROM KNOWLEDGE:

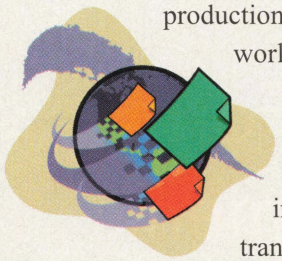
New Xerox Graphic Arts Solution Portfolio

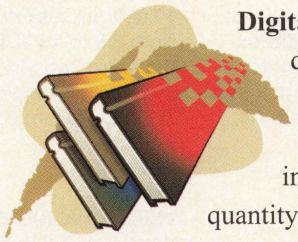
The recently announced Xerox Graphic Arts Solution Portfolio consists of five solutions that combine hardware, software and services from Xerox and its partners. Brief descriptions follow:

1:1 Marketing—draws upon company knowledge about customers and prospects to create high-impact personalized documents that carry compelling messages for an audience of one. The process uses variable information to produce customized pieces within a single print run. Benefits include higher response rates, reduced direct marketing costs, enhanced customer loyalty, and a change in the value structure from cost per piece to cost per lead.



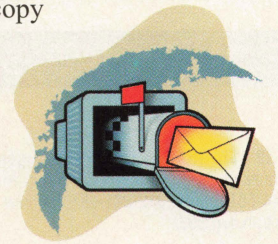
Global Distribution—provides a dependable, efficient way to distribute and manage documents across geographies. Benefits include fast and secure network distribution; access to global production and publishing services worldwide; quality guarantees for remote production; and access to services for doing global business, including re-formatting, translation, and multinational document management.



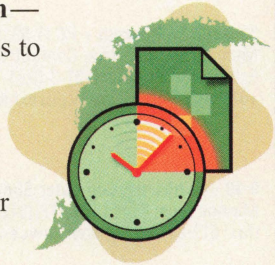


Digital Books—uses print-on-demand technology to enable book printers to digitally store titles and instantly print the desired quantity. Benefits include the elimination of overprinting, thereby negating the associated costs of inventory management, warehousing, obsolescence and destruction, and the opportunity to gain additional revenue by providing books that would other wise not be available, such as out-of-print or niche titles.

Internet Delivery—enables document service providers who output hardcopy statements and bills to deliver that data via the Web. Recipients can pay online or by the traditional paper method. Benefits include support of cross selling and 1:1 marketing through collection and analysis of personal data, speedier statement processing, and reduced production costs.



Just-In-Time Documentation—enables graphic arts companies to align more closely with the needs of client organizations to provide updated, accurate manuals, user guides and other documentation from digital storage. Benefits include reduced warehousing, obsolescence and fulfillment costs; faster time to market; and improved operational control, customer service and customer satisfaction.



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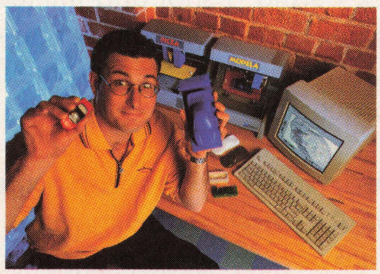
From 3D scanning and modeling to hi-fidelity printing, Roland gets it right.

Roland DGA Corporation is an established leader in digital input and output devices for graphics professionals worldwide. With 3D scanners, 3D modeling machines and wide-format high-resolution inkjet printers, Roland offers something for everyone in the computer graphics world.

Roland 3D Scanners. The PICZA 3D desktop digitizing scanner is a powerful design tool that incorporates piezo-probe automated scanning technology to produce wireframe models of 3D objects. The PICZA can scan objects as diverse as steel machine parts, flexible gift-wrap bows or sculpted clay figures, to a 4" x 6" x 1-1/2" maximum. The PICZA scan can then be saved by the included Dr. PICZA software in .DXF, .STL, .VRML, Grayscale (.BMP), Bitmap (.BMP) or Point Cloud (.TXT) file formats and exported to popular graphics, animation and CAD software programs.



PICZA 3D Scanner
- 3D desktop digitizing scanner
- Up to .002" resolution
- Scans soft and hard objects
- Creates 3D wireframes
- Output to MODELA or export to animation and CAD programs

MODELA 3D Modeling
- 3D desktop milling machine
- Ideal companion to PICZA 3D scanner
- Mills wax
- Import 3D files from popular CAD software

PICZA scans can also be exported directly to the Roland MODELA 3D desktop digitizing plotter to create prototypes, models or molds. PICZA is available for only $1,195 or bundled with the MODELA for $1,995. The PICZA can be purchased from Roland dealers or directly on Roland's web site at www.rolanddga.com/picza/cgw.

Steve Varner, Primary Sculptor and head of Varner Studios produces toy action figures for major toy manufacturers and fast food restaurants. "The PICZA and its companion MODELA are great when existing sculpts need to be created at different sizes," Varner says. "We scan our original sculpt with the PICZA and output a wax model at a different size on the MODELA. This saves us a lot of time. My specialty is portraits - getting the faces right - and PICZA is perfect for that kind of intricate detail." See Steve Varner's work online at www.varnerstudios.com.

Roland 3D Modelers. The MODELA 3D desktop modeling machine produces prototypes from the PICZA's .PIX files or from .DXF or .STL files from other CAD programs. The files are sent to the MODELA, where they can be rotated and scaled on screen and viewed from any angle. The user selects the type of material and cutting tool from the library of options that comes with the included MODELA Player software. Materials include chemical wood, jewelers wax, foamboard or Styrofoam. The MODELA accepts most 1/4" router bits and has an optional 1/8" tool holder. MODELA is available for only $995 or bundled with the PICZA for $1,995. The MODELA can be purchased from Roland dealers or directly from Roland's web site at www.rolanddga.com/modela/cgw.

Full Line of 3D Products. Roland offers a full line of 3D products including larger 3D scanners, plotters, engravers and heavy-duty modeling machines for a variety of scanning and prototyping needs. Visit booth #568 at Siggraph for a preview.

Roland Hi-Fi JET Printers. Roland's award-winning Hi-Fi JET Piezo inkjet printers offer unrivaled 97% PANTONE® spot-color accuracy. With the Roland Hi-Fi JET, the limitations of CMYK printing are just a memory. In tests by Pantone, Inc., the Hi-Fi JET was able to achieve over 97% of the PANTONE Colors using long-lasting pigment inks. This wider gamut means photos, graphics, illustrations and proofs will be reproduced with stunning realism and intensity. The Hi-Fi JET delivers the best in every category: True 1440 dpi resolution ... you won't hear us talking about apparent resolution. 50 and 40 inch print widths. UV stable pigment inks for vivid colors and long life. Easy set-up and no-mess operation. Mac® and Windows® compatibility. And best of all, Roland's global reputation for reliability and customer support.

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See Roland at Siggraph booth #568

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Lucy, shown here, co-hosts CBS Television's Wheel of Fortune 2000– a kid's version of the classic Wheel of Fortune game show.

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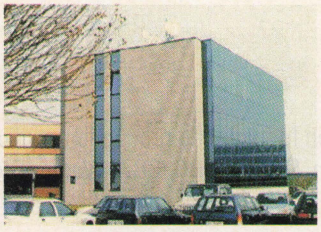
Ten years of R& D

Founded in 1989, GESTEL develops and markets advanced 3D solutions for professional designers and artists. GESTEL is dedicated to creating computer aids that improve not solely production, but that also enhance design creativity. Providing superior customer support through continuous improvement in product technology, employees skills, and business infrastructure is a fundamental component of its mission.

GESTEL main product is the award-winning solidThinking, an advanced 3D environment that is now available also on the Windows platforms after being available only on the Unix for several years.



GESTEL has offices in Vicenza, Italy and Montecarlo, France and, in order to keep building on its evolving based foundation, operates together with a staff of programmers from diverse nations and directs continuing marketing research and development.

solidThinking, a breakthrough in NURBS modeling

Being a pure CAID (Computer Aided Industrial Design) software, solidThinking has been developed to meet the specific needs of industrial designers and models creators. Available on Windows 95/98 and NT (NT is strongly recommended) *solidThinking* offers, in a unique integrated environment, tools to create and alter a 3D model's shape and surface qualities as well as a complete set of features for design presentation like photo-realistic rendering and lighting.

solidThinking is not just a useful tool for reproducing a model. It is much more: it stimulates creativity thus becoming an irreplaceable tool for developing new shapes and exploring as many design alternatives as possible.

It is also for this reason that, six months after its introduction on the Windows market, solidThinking has been already adopted by many international companies such as Compaq Computers, The Computer Film Company (CFC), Daihatsu, Fiat, Kenwood Design, Nestlé, Pentel, San Pellegrino, Seiko, Stanley Electric.

Compelling advantages for the designer

solidThinking enhances designer creativity but also compresses the product development cycle and significantly reduces its costs.

Thanks to the full support of OpenGL graphics libraries solidThinking offers the highest interactivity during any modeling phase. A tough Construction History makes a great difference between solidThinking and other NURBS modeler available on the market. In fact, the Construction History empowers one to change any parameter at any given time and view any of those changes instantly. The impact on productivity is terrific.

The integrated support of all industry leading rendering techniques (hidden line, scan-line, ray-tracing, radiosity and RenderMan) meets almost any need for photorealistic presentations.

Not only NURBS: solidThinking 3.5

The numerous new features make of solidThinking 3.5 the choice for the creative 3D professionals:

- OpenGL and NEW DirectX support.
- NEW High performance redrawing with complex scenes, both in wireframe and shaded visualization mode.
- A complete set of 2D curve drawing tools.
- Deformations: bend, lattice, shear, stretch, taper, twist, warp.
- Power NURBS modeling.
- NEW Advanced polygonal modeling with support of n-side polygons.
- Construction History.
- NEW C2-continuity surfaces (Class-A).
- The most sophisticated modeling tools including Bi-Rail, NEW N-Side, CurvesNetwork, Blending, Fillet, interactive Trim curves, Booleans.
- NEW Isoparm Extract modeling tool.
- NEW Surface Tangency Align modeling tool.
- NEW Simplify Curve and Simplify Surface. Reduce number of points of a curve or a surface given a tolerance.
- NEW Points Cloud modeling tool.
- NEW Evaluation tools.
- NEW Full support for Interactive Subdivision Surfaces.
- Advanced hierarchical browser.
- NEW Unlimited number of construction planes.
- Unlimited number of layers.
- NEW Units of measure.

- Faster rendering with transparent / reflective objects.
- NEW Transparent drawing mode.
- All industry-leading rendering techniques are supported: hidden line, scanline, ray-tracing, hybrid radiosity and RenderMan.
- Multi-threaded and multi-processor rendering. Unlimited resolution.
- Soft Shadows.
- Feature following anti-aliasing for the highest-quality output.
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- Easy Upgrade: Beginner to Professional

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CINEMA 4D SE

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Great for beginners, Internet/multimedia graphics developers and even flying logos for video. Limited to position, scale and rotation animation. Renders up to NTSC and PAL resolution. Includes the Instant Space CD, a modular spaceship and intergalactic scene creation set. (US SRP $195)

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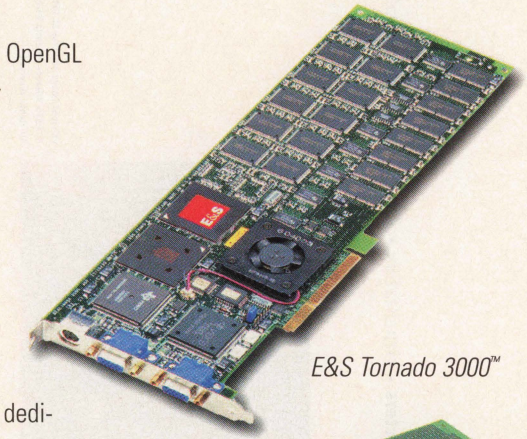

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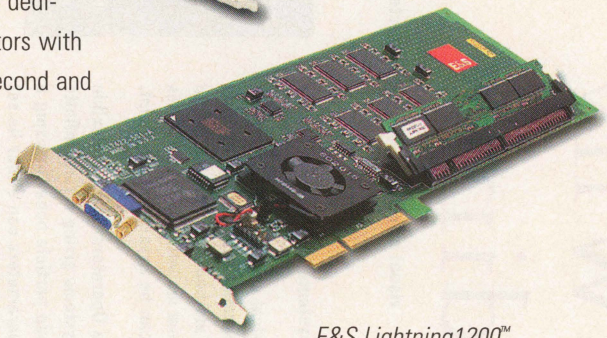
E&S Tornado 3000 is our highest-performance, full-featured accelerator. With 62 MB of memory (32 MB dedicated to textures), you can have true-color resolutions to 1920x1200. Or, you can display on two monitors with one card - each monitor displays at 1280x1024, true color. With texturing at up to100 megapixels per second and 5 million triangles per second, you have industry-leading fill rates for working with complex models.



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E&S Tornado 3000 and E&S Lightning 1200 are designed for and tested with professional OpenGL, Windows NT® applications like SOFTIMAGE, LightWave 3D, Maya, and 3D Studio MAX. Based on REALimage™ technology, both cards feature DYNAMICgeometry™ drivers, which are the result of 24 months of joint development effort with Intel. By fully utilizing the new Streaming SIMD Extensions, you get the power of a geometry accelerator in your CPU. It's no surprise that Intel chose E&S graphics cards to demonstrate their new Pentium®III processor.

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Why Houdini?

visual effects • games • characters • visualization • design • realtime animation

• POPs • L-systems • procedural SOPs

Natural phenomena, physical events, plant life: some of the visual effects that Houdini excels at recreating. Its powerful procedural methodology enables you to work with all the steps from modeling to rendering as part of a live network that can be tweaked at any point.

Houdini's POPs (Particle Operators) is more flexible than conventional particle systems giving artists infinite control over single or group particle behavior using a range of tools where parameters can either be set directly or driven by events, timing or expressions. POPs can and has been used to create natural phenomena such as water drops, oceans, ice, fire, smoke, star systems and explosions of unmatched realism.

Houdini's L-systems apply the power of proceduralism to a rule-based system allowing you to grow truly organic-looking branching structures. L-systems are integrated with our procedural SOPs (Surface Operators) in Houdini's modeler enabling you to take any piece of geometry or part of a particle system and place it on the branching structure as it grows. This greatly simplifies the process of affixing particle leaves on growing trees or metaball nodes on neurons.

What Dreams May Come
image courtesy of Digital Domain
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• procedural modeling and animation • channels • expressions • IK • CHOPs

Houdini® gives you a myriad of choices for bringing a character to life. Its procedural paradigm allows you to adjust a hand shape or change a texture and see the results instantly. Animate these changes and watch your character morph as it walks.

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For motion capture animators, CHOPs (Channel Operators) is the most powerful and extensive toolset available for working with motion capture and other channel data. It gives animators new tools to edit and combine motion, layer motion-on-motion, manipulate mocap data, add sound and apply facial animation with lip sync. CHOPs can also be used as a realtime motion input and recording unit, allowing for realtime puppeteering.

All of these features are available within an integrated environment that allows data to be shared across the package.

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Side Effects Software has been producing the world's premier procedural 3D animation package since 1987. Our worldwide list of clients include: Computer Film Company, Digital Domain, DreamWorks SKG, Electronic Arts, Namco, Nickelodeon, Rhythm & Hues, Sega, Sony Pictures Imageworks and many others.

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The Rendering Problem

Image quality. Whether you create images for animation or visualization, you want to present an image with the highest level of quality possible. Unfortunately, the technique that provides the most photorealistic image quality, ray tracing, is just not practical. It's software based, and it's too slow, unless you have the luxury of a render farm. But that's expensive and difficult to install and maintain. For most studios, it's just not an option.

A Rendering Appliance

RenderDrive is a revolutionary breakthrough in rendering technology; the first and only rendering appliance to use specialized processors dedicated to the ray tracing task and to offer the power of a multi-node render farm in a single, compact unit.

RenderDrive delivers high-quality ray traced images for animation and visualization. In the past, only the largest studios have had the resources to utilize ray tracing to any great extent. Now, with RenderDrive, ray traced rendering is available to animators in every sector of the market.

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RenderDrive delivers plug-and-play integration into your existing studio network. Through its software plug-in, RenderDrive can be accessed from within the normal 3DSMax and 3DSViz user interface. Unlike many other ray tracers, RenderDrive works with the native standard materials and integrates with Video Post and many third-party plug-ins.

RenderDrive is a reliable and robust hardware-based ray tracing appliance, and, as a shared network device, it can be accessed by any workstation in your studio. Quickly and easily installed onto your network, RenderDrive requires virtually no administration once it's up and running. You can use any standard web browser to access the on-board job queue where you can keep track of and reschedule your rendering tasks.

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RenderDrive is the first and only rendering appliance that offers an end-to-end, platform independent solution to your rendering needs. With RenderDrive, you no longer have to think about working around the limitations of your rendering resource. You have the freedom to focus on the creative tasks of modeling and animation, while RenderDrive concentrates on delivering images of the highest quality.

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Intense3D®: First in Professional 3D Graphics Accelerators

Intense3D is a world leader in 3D graphics accelerator technology, with a 30-year history of graphics innovation reaching back to the inception of the computer graphics industry. Today, Intense3D's Wildcat 3D Graphics Accelerators are the graphics of choice for the industry's premier workstation vendors, including Compaq, Dell, Fujitsu, IBM, Intergraph Computer Systems, and Siemens.

Wildcat® 3D Graphics Technology: Unparalleled Innovation in Graphics

Wildcat 3D graphics products are based on Intense3D's Wildcat 3D Graphics Technology – the result of an extensive engineering effort designed to shatter the limits of 3D graphics performance. Wildcat 3D Graphics Technology features a rendering ASIC that contains over 8.4 million transistors, a 3 GFLOP geometry accelerator with over 9.5 million transistors and the most scalable graphics pipeline architecture ever developed – Intense3D's innovative ParaScale architecture. These breakthrough technologies are the culmination of more than 100 engineer-years of development, resulting in dozens of patented and patent-pending innovations. With this technical foundation, it's obvious why Wildcat graphics products have become the de facto standard for professional 3D graphics, with the most support from hardware and software vendors in the industry. Make your workstation a graphics powerhouse with Intense3D's Wildcat 3510, Wildcat 4000, or Wildcat 4105. And coming soon…

Wildcat 4110: There's a *new* cat in the jungle

Intense3D's next-generation graphics offering – the Wildcat 4110 – delivers radically advanced features at an unbelievably low price. These features include fully accelerated 3D volumetric rendering and multi-sampled, full-scene anti-aliasing with Intense3D's patent-pending SuperScene Anti-Aliasing technology. The 4110's huge, dedicated 64 MB frame buffer and 64 MB texture memory (128 MB Total!) enable rich, photorealistic shading and highly detailed textures – always in true color, with maximum depth accuracy, and with double buffering enabled. The Wildcat 4110 roars through complex 3D applications, delivering advanced features, raw performance, and unmatched image quality.

Wildcat 3D Graphics accelerators deliver the savage, untamed performance that allows you to unleash your own creative power on the most advanced professional 3D applications.

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Polhemus

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Polhemus offers a complete family of motion capture products. Providing total freedom of movement with the ability to capture data in real-time, the newest generation of STAR*TRAK RF Wireless Real-time Motion Capture Systems easily tracks the movements of multiple characters.

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FASTRAK is an ideal solution for applications which need to capture a number of data points with a high degree of accuracy.

That's why you'll see the FASTRAK name inside an incredible array of products - from image-guided surgery and biomechanical gait analysis systems to 3D head mounted displays and gloves — and our very own FastSCAN.

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Typhoon V.2.1

DreamTeam Ltd., founded in 1995, develops innovative solutions for the visual entertainment industry. DreamTeam's Typhoon is an off-the-shelf, real-time animation software for production and post-production applications.

Offering full support for leading 3D animation packages (A|W Maya, A|W PowerAnimator, 3D Studio MAX, Softimage3D) as well as a full range of motion capture and other hardware devices, Typhoon lets you import your creations and animate them in real-time. Perfect for live to air/ live to tape productions, Typhoon allows the integration of high quality virtual characters into live broadcasts, with realistic interaction between live actors and animated elements.

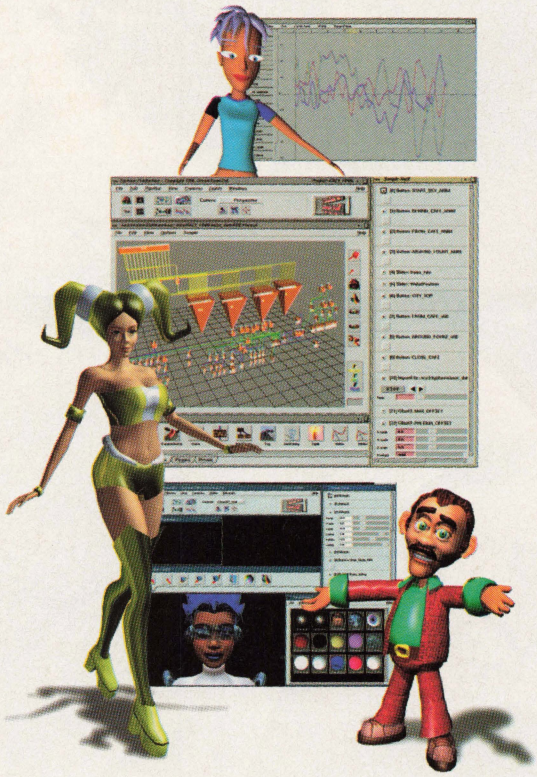
Typhoon also serves as a post-production solution. Equipped with a complete set of motion editing tools, you can edit and tweak motion data recorded in Typhoon for later export to animation packages for further manipulation and rendering.

Typhoon takes a unique approach to real-time technology, achieving high performance standards on a convenient, easy to use platform:

Real-Time Ease of Use: Controlling even the most intricate 3D scenes is made easy with Typhoon's Pipeline, a convenient, intuitive 3D environment where scene elements are arranged for real-time manipulation. Within the Pipeline, users drag and connect pipes between graphical representations of sources (input devices), filters (data manipulators) and sinks (scene elements).

Real-Time Quality: Typhoon introduces the ability to animate complex Single Skin characters in real-time. These realistic looking characters are built as a single skin body rather than as separate parts connected at the joints. This innovation creates smooth deformations that allow for realistic bending and soft skin movement.

Real-Time Efficiency: Typhoon's exceptional real-time rendering capabilities allow users to control complex characters in real-time on the full range of SGI machines as well as on NT based machines.



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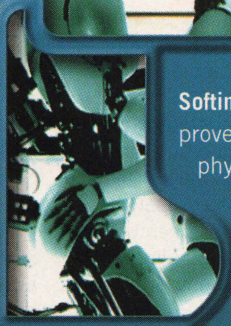
Customer Spotlight: of Love and Robots

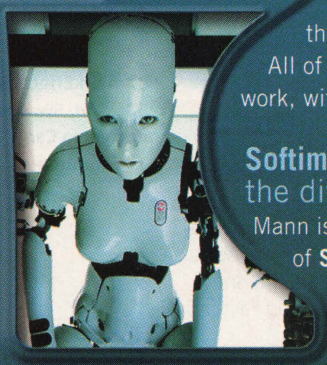
Glassworks and Softimage® Bring Björk to Life

"All Is Full Of Love", the latest video offering from Björk, is an esoteric blend of reality and robotics, sensibility and sensuality. The video proceeds through an erotically-charged representation of machine-controlled carnality—all with not one visible human.



A moving challenge.

"The robot that they had was just a model... you could position it, but it couldn't move on its own," says James Mann, 3D Artist and **Softimage 3D** expert at London's Glassworks. "We had to work really hard and fast to replace all the robot's moving parts with 3-D models and representations. Whenever the heads move from side-to-side or however, we had to create an equal but opposite 3-D head, then composite Björk's eyes onto it. We also had to realistically animate her jaw, making it move up and down as she sang. And when the huge robot arms constructing her and her partner move? Well, that was 3-D as well."



Björk

An illuminating experience.

Mann claims the real challenge was realistic lighting. "Obviously, there were a lot of models to be made. We had Björk's face scanned, but everything else had to be created: the neck, the back of the head and virtually everything else was all developed in **Softimage 3D**. But it was the lighting that proved to be really difficult, because the physical scene was very brightly lit. We ended up with about 30 lights in each CG scene. We arranged them in grids to create an illusion of radiosity. I actually ended up creating a rough model of the set, then doing a separate pass for reflections. All of that was quite subtle and painstaking work, with a lot of layers involved."

Softimage 3D made all the difference.

Mann is quick to extol the creative virtues of **Softimage 3D**: "I like Softimage 3D, and the lights in it," says Mann emphatically. "It's a really nice package to use and I've been using it for about 5 years now. I usually like to work with all the renderers I can, because a variety of tools usually helps on projects, but I only used **Softimage 3D** on 'All Is Full Of Love.' It was a lot faster than any alternative, believe me! That makes a big difference on a project like this one. When you've got so many things to do, and if you can render something faster, it's invaluable."

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CORPORATE OVERVIEW

Alias|Wavefront Delivers Workflow Solutions for Creative Advantage

As the world's leading innovator of 2D and 3D graphics technology, Alias|Wavefront develops award winning solutions for the film and video, games, interactive media, industrial design, and visualization markets. In working together, and understanding the needs of the customers they serve, the Entertainment and Design Business Units create a synergy that benefits customers with continual innovation in software development. The company's open workflow solutions give artists and designers a distinct creative advantage no matter what their discipline.

With more than 550 employees worldwide, Alias|Wavefront is an independent software company wholly owned by SGI with headquarters in Toronto, Canada and technical centers in Seattle and Santa Barbara. Alias|Wavefront has worldwide distribution via a network of Channel Partners and sales offices located in North America, Latin America, Europe and Asia.

The Markets and their Technologies

ENTERTAINMENT Alias|Wavefront has built a powerful suite of creative tools for feature films, broadcast television, post production, electronic games, interactive media and location-based entertainment markets.

Maya™ Complete, makes state-of-the-art technology accessible to a broad range of computer graphics professionals. Maya™ Unlimited, which includes the company's most advanced technology, has been used a large number of groundbreaking films, such as *Mighty Joe Young, The Matrix,* and most recently, *Star Wars: Episode 1: The Phantom Menace*. With the release of Maya 2 in June 1999, both Maya Complete and Maya Unlimited are available for Silicon Graphics IRIX and Windows NT platforms.

In the fall of 1999, Alias|Wavefront will continue its unprecedented pace of product development and release Maya 2.5. Perhaps the most important advance in Maya 2.5 is Maya™ Paint Effects, a groundbreaking brush-based technology included in both Maya Complete and Maya Unlimited.

Alias|Wavefront's film, video and game customers include Blue Sky, Cinesite, CNN, Digital Domain, Dream Quest Images, Industrial Light & Magic, Pacific Data Images (PDI), Pixar, Santa Barbara Studios, Sony Pictures Imageworks, The Walt Disney Company, Nihilistic Software, Square, Core Designs, and Factor 5.

Imaging technologies: Animators and visual effects artists use Alias|Wavefront's tools to bring together and manipulate 3D data with live, 2D action. The company's imaging technologies include applications for compositing, visual effects creation, video capture and playback for the computer graphics (CG) production markets. The products, which include Maya Composer for IRIX and Maya Fusion for Windows NT, fit seamlessly into the production workflow.

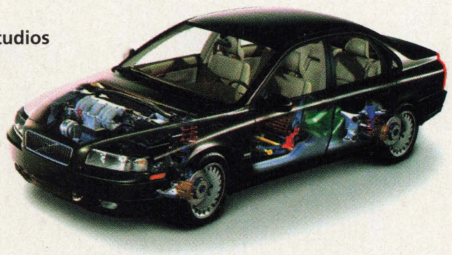
Industrial Light & Magic used Maya software to create the thrilling podrace sequence in *Stars Wars: Episode One: The Phantom Menace*

DESIGN For more than 14 years, Alias|Wavefront has been the world's leading developer of 3D software for the consumer products and transportation markets, helping companies to design better products and to bring them to market faster. Its Studio™ family of products is available for Silicon Graphics®, IBM® workstations and Windows NT platforms and for the Sun Solaris operating environment.

Studio|Tools

The Studio 9 family, which includes AutoStudio™, Studio™, StudioPaint™, SurfaceStudio™, and DesignStudio™ provides a comprehensive suite of tools that enable complete integration throughout the entire shape definition process – from concept sketches through engineering and manufacturing.

Motion Effects Studios Mex Ad, Sweden for Volvo Car Corporation



Transportation: AutoStudio is now the industry standard for automotive design and styling and provides transportation designers with freedom and flexibility for total creativity, combined with precision and accuracy. It's the industry's best technology for designing, 3D modeling, rendering and engineering integration.

SurfaceStudio, a technical surfacing product for the development of Class-A surfaces, offers advanced modeling and reverse engineering tools, real-time diagnostics and scan data processing technology. It provides a complete suite of tools for creating surface models that meet the stringent levels of quality, accuracy and precision required for integration with engineering and manufacturing processes.

Consumer Products: Around the world, designers also use Alias|Wavefront's CAID (computer aided industrial design) software to produce award-winning consumer product designs for everything from laptop computers, sporting equipment, cellular telephones, medical equipment to children's toys, and fashion accessories.

Alias|Wavefront's design customers include AT&T, Apple, BMW, Boeing, Fiat, Ford, Honda, General Motors, Italdesign, Kodak, Mattel, Renault, Rollerblade, Teague and Timex.

To learn more about Alias|Wavefront's software for the entertainment, design and visualization markets, visit the company's Web site at **http://www.aliaswavefront.com**, or write to us at: Alias|Wavefront 210 King St. East Toronto, Ontario Canada M5A 1J7 Tel: 416-362-9181

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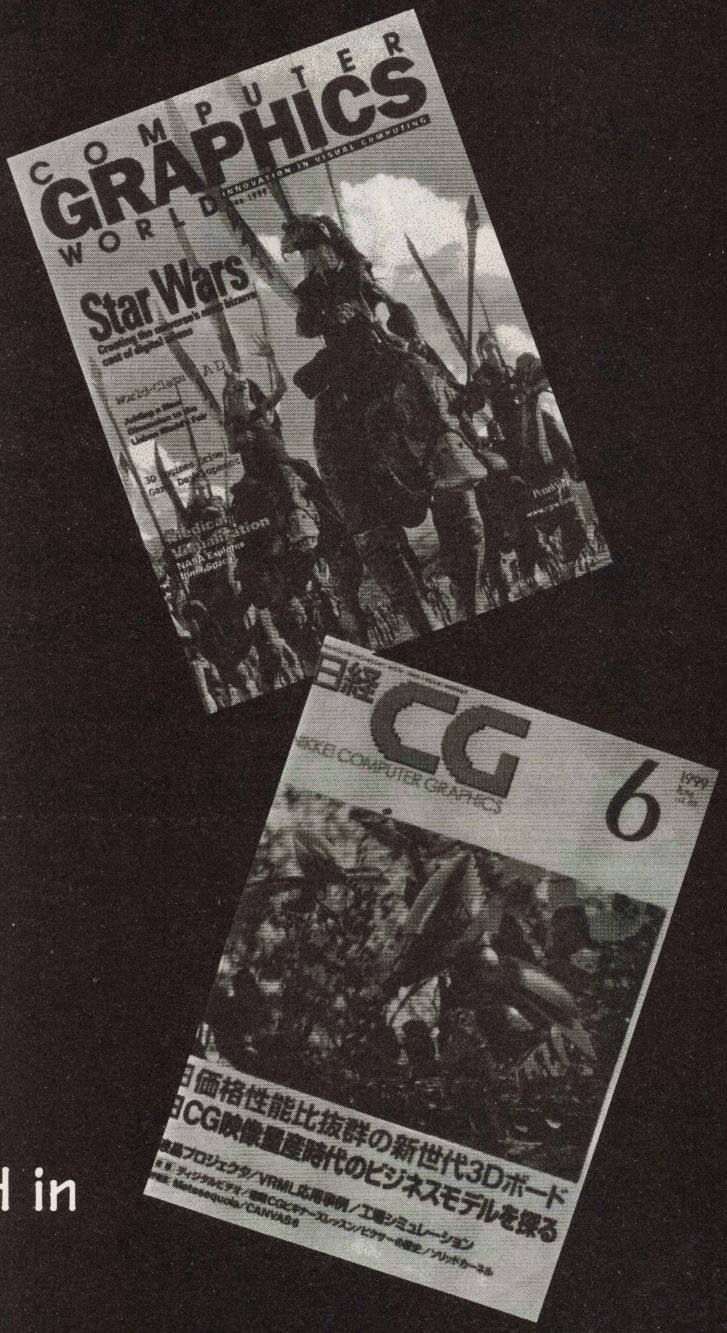

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- As DVD-RAM capacity grows, future drives will read current media; data can be accessed today and tomorrow.

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Interface	SCSI-2 / Fast SCSI, Half pitch 50-pin connector w/terminal function	
Supporting Disc	**Write**	DVD-RAM & PD
	Read	DVD-Video, DVD-ROM, DVD-R, Video CD, CD Audio CD-ROM & CD-R/RW
Average Seek Time	**DVD-RAM**	120ms
	DVD-ROM	85ms
	PD	85ms
	CD-ROM	85ms
Sustained Data Transfer Rate	**DVD-RAM**	1,385 KB/s
	DVD-ROM	2,770 KB/s
	PD	518-1,141 KB/s
	CD-ROM	Max 3,000 KB/s
Buffer	2MB	
Loading Method	Front Loading	

Panasonic DVD-RAM Media

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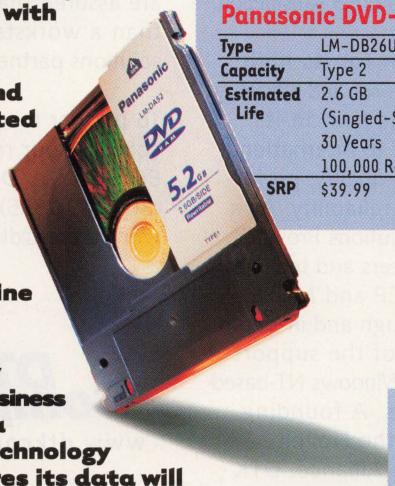

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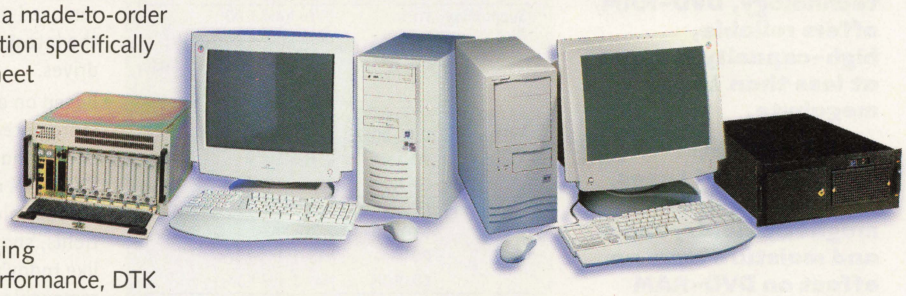
DTK Is More Than a Workstation It's a Solutions Partner.

DTK is committed to its customers to work with them as a partner. As the leader in customized workstations, no company comprehends better than DTK the importance of thoroughly understanding the needs of any application and melding them with the perfect workstation. As a partner who understands computer graphics and how to customize and optimize workstations, DTK can help users conquer every challenge. For any specific application, DTK offers customers complete networking solutions, bringing them a made-to-order turnkey operation specifically designed to meet their individual needs.



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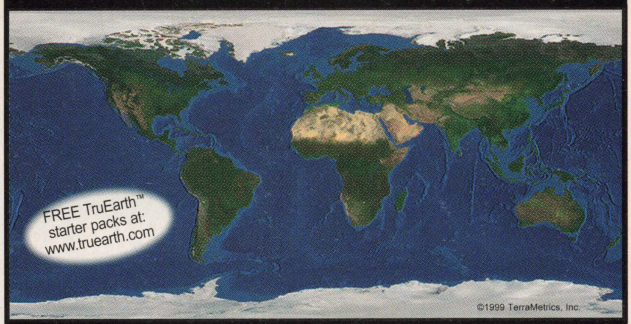

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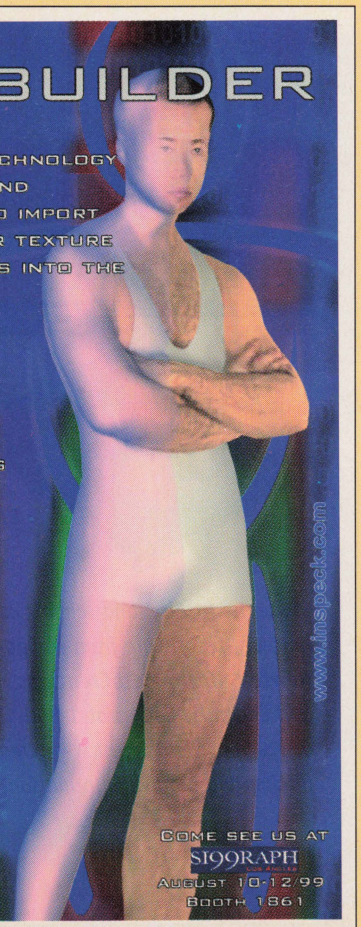

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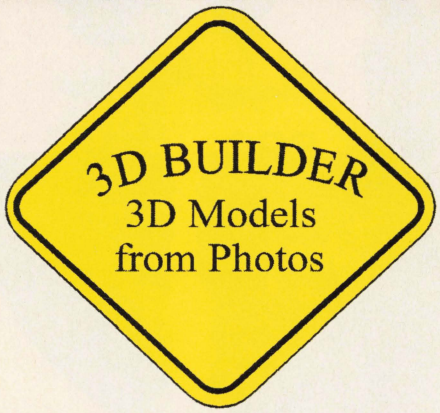

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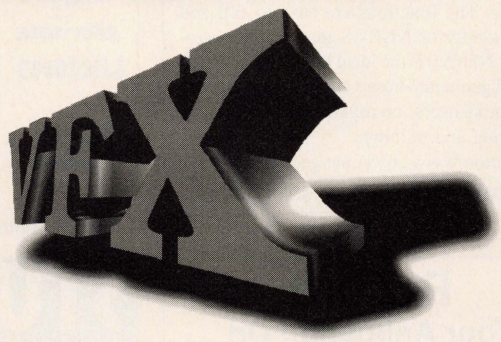

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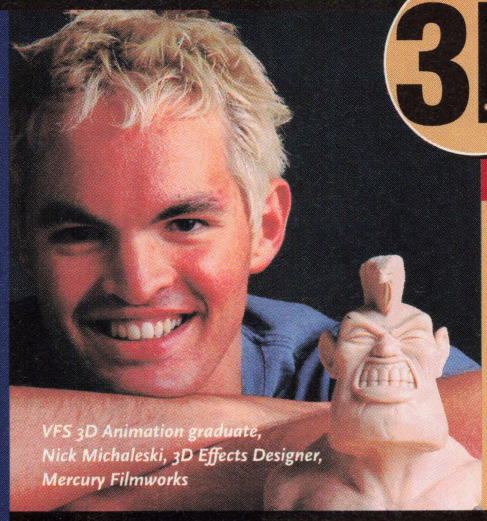

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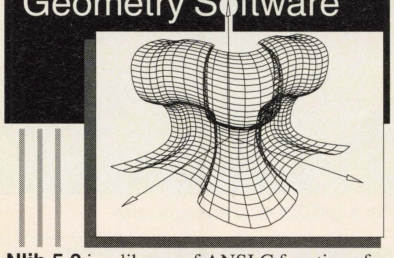

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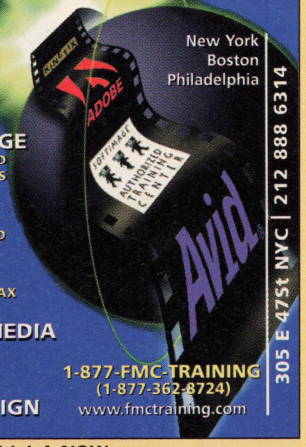

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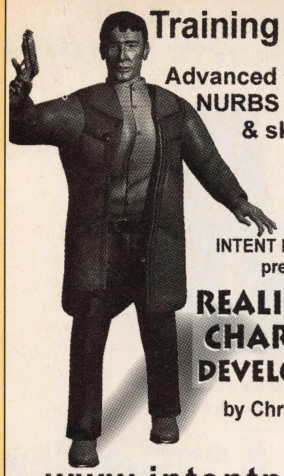

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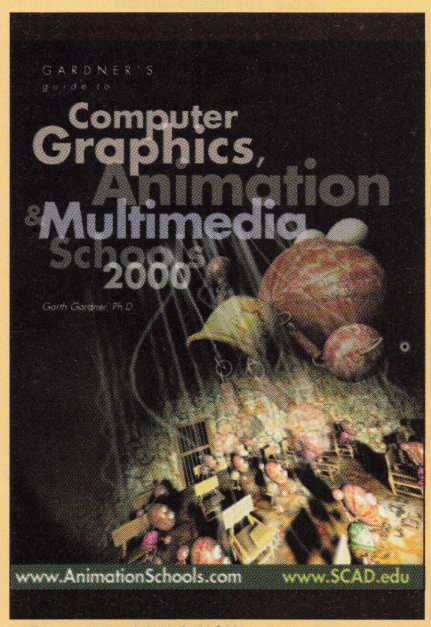

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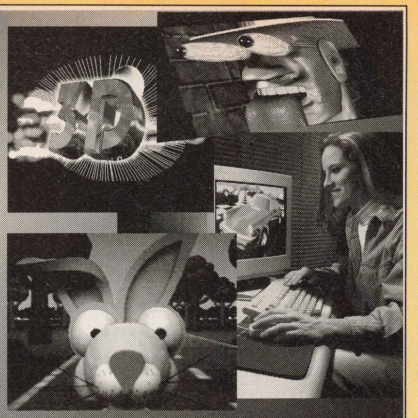

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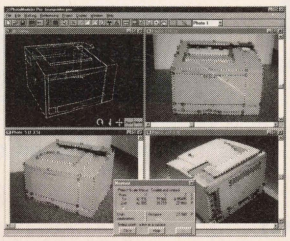

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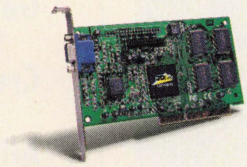

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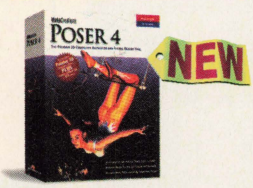

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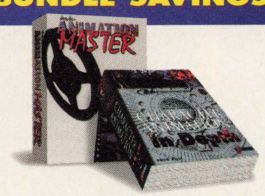

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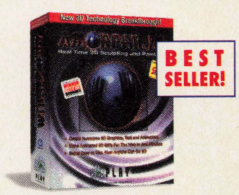

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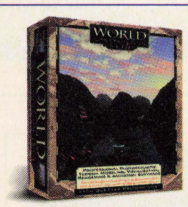

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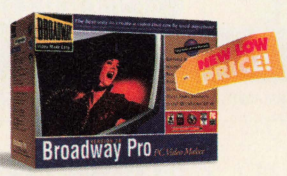

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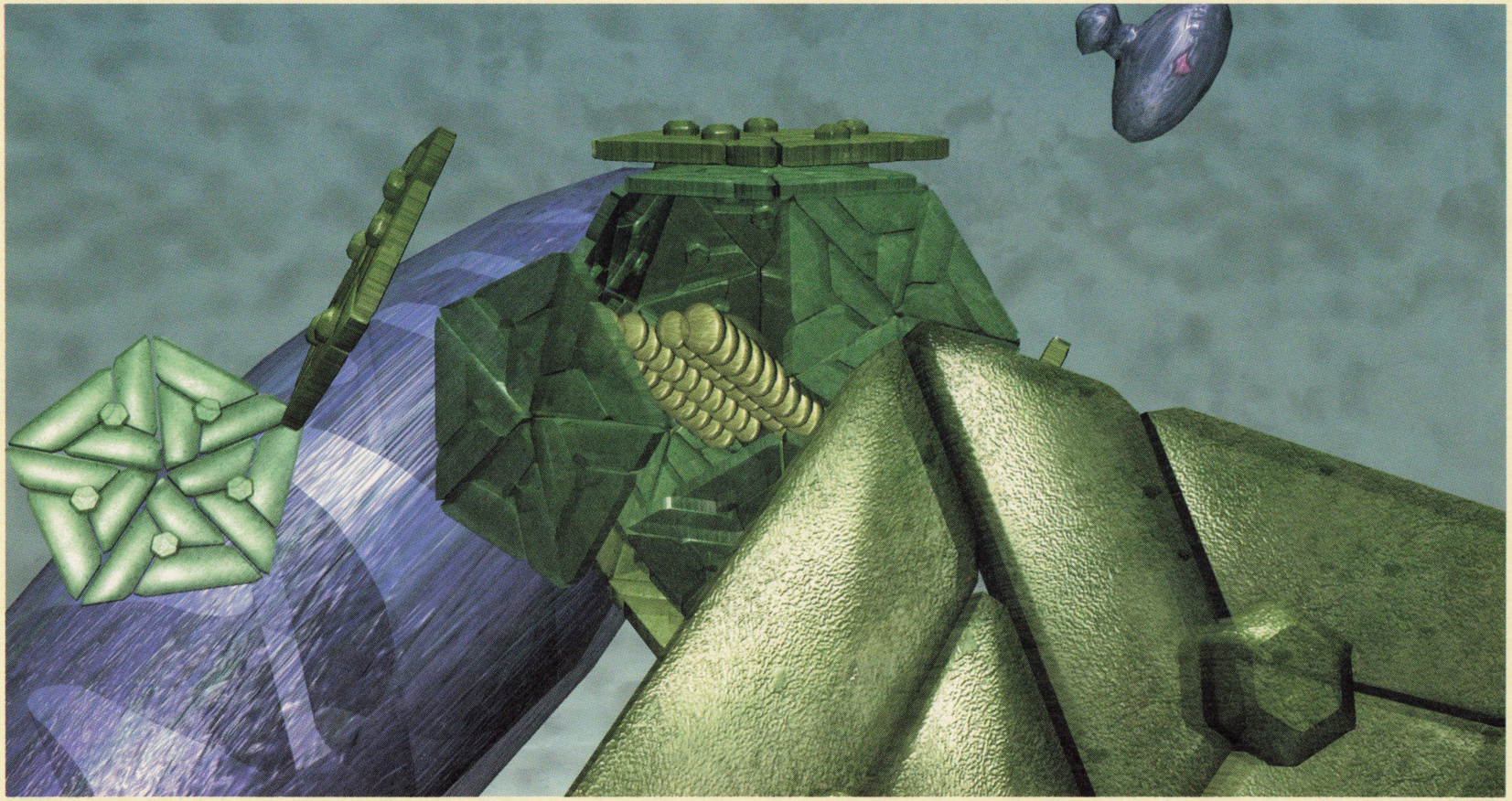

Last year, biomedical researchers at the University of Calgary discovered that a naturally occurring respiratory virus, called the reovirus, can kill cancer cells. Infecting a single cancer cell with a reovirus particle spawns thousands of new reovirus particles, which then infect and eliminate neighboring cancer cells. Visualization specialists at Netera Alliance Inc. (Calgary, Alberta, Canada) in association with the University of Calgary created an interactive visualization of this destructive process to help project-leader Dr. Patrick Lee and colleagues in the Biomedical Research Department illustrate their findings to the public. In this image, the reovirus (front, center) is in the process of shedding its protein coat (hexagonal structures) and releasing its genetic code into a cancer cell. The spiral tubes within the reovirus are the viral DNA. The elongated purple oval is the cancer cell's mitochondria. And the structure floating above the reovirus to the right is an intracellular protein. The production team created the simulation using Softimage 3D Extreme running on Intergraph TDZ2000 graphics workstations.

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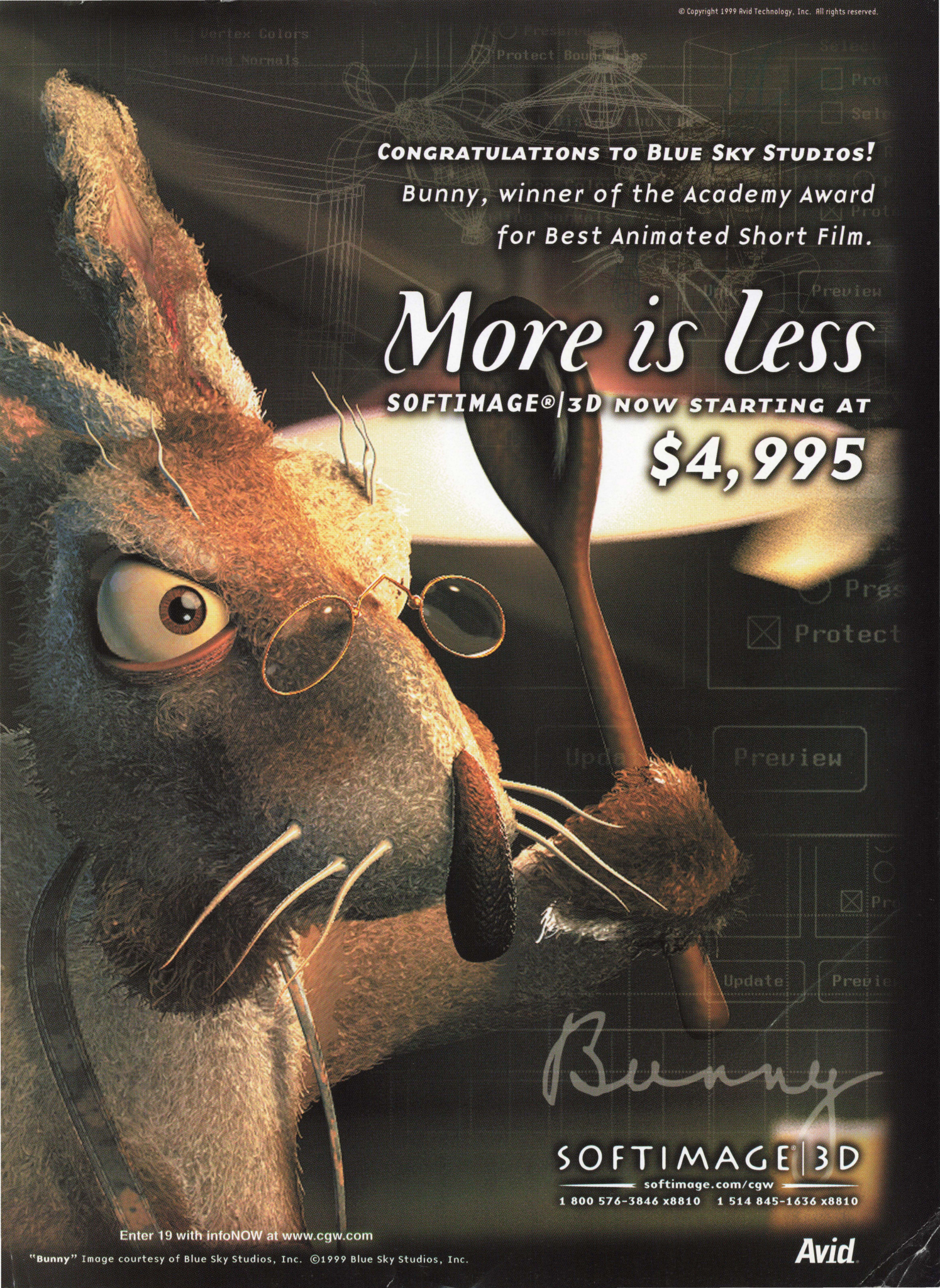
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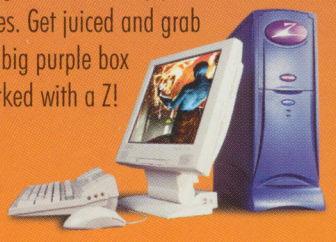

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